CHAPTER 13

Sleep/Wake – Neuromuscular Skeletal Connection

What roles does gravity play in maintaining the wake/sleep cycle? Does body posture influence sleep? What is the relationship between muscular movement and consciousness? How does the brain reduce information processing and thus reduce its need for sleep? Do primitive reflexes influence sleep? What is the relationship of the Moro primitive startle reflex and sleep apnoea? Which primitive neural reflex, if not suppressed during the development out of the womb, increases the risk of sleeping problems? What is the role of the vestibular system in maintaining a position in space or head on the pillow? Are babies born prematurely or through caesarean section, at higher risk of sleep disorders? What is the role of the tongue in sleep apnoea?

GRAVITY AND MUSCULAR POSTURE/ NEURAL SYSTEM

Life on Earth evolved in the presence of a static gravitational field. For this reason, it is perhaps not surprising that both acute and chronic exposure to altered gravitational fields can affect physiological regulation. Gravity plays a role in all life processes through the expression of circadian rhythms and on the suprachiasmatic nucleus; the circadian pacemaker.[1,2]

Gravity is one of the primary stimuli involved in developing neural reflexes. Gravity activates muscle spindle cells, which cause motor responses. To live on this terrestrial planet requires a sensing system that can help orientate the body itself in gravity space. Obviously in the development of the human body, nerves, sensors, muscles, ligaments and bones, are developed to help us orientate in gravitational space, in such a way that the structural components (head, spine, pelvis, and feet) work together to allow posture; benefiting movement and special positioning.

Our posture is maintained by the positioning of our bones (including cranial bones) within the Cartesian coordinates of X, Y, and Z.

The cerebellum, vestibular system, brain stem limbic and prefrontal cortex are the most active areas in the brain as far as activation, movement and gravity are concerned.

From an evolutionary perspective, adaptation to gravity is very important for the safety of the organism, as well as for the conservation of energy. Adaptation to gravity is required for all basic survival reflexes such as fight/flight, digestion and procreation. In all mentioned responses, the body needs to assume the right posture for the desired action.

When considering postural adaptation to gravity, architecture of the spine plays a key role.

All organised matter such as the human body, have a focal point on which gravity acts - its centre of gravity. The centre of gravity of the human body should ideally be located in the joint between the fifth lumbar and first sacral vertebrae. This joint is cushioned and supported by cartilage to allow a full range of easy movement. If this base plane is distorted and is not correctly aligned, it will create stress in the supporting muscles. If these muscles do not work evenly, the pelvis itself will be out of balance, resulting in poor posture. ***(See Figure 13.1)***

Posture refers to the positioning or alignment of the various parts of the body in relation to one another and gravity. Proper body positioning and alignment are important considerations in preventing many of the problems that develop from the stresses of work, aging, and fatigue. Proper posture helps prevent: fatigue, sleep disturbances, headaches, eye strain, and chronic muscular tension. In addition, good posture can help improve circulation and digestion, enhance sleep, and prevent cramping of internal organs. Correct postural alignment can boost self-image and clear the mind, contributing to sharper senses. In addition to contributing to healthier emotional states and overall vitality, good posture can make exercise more enjoyable, improve general fitness and enhance performance. Proper posture can improve your quality of life and sleep.

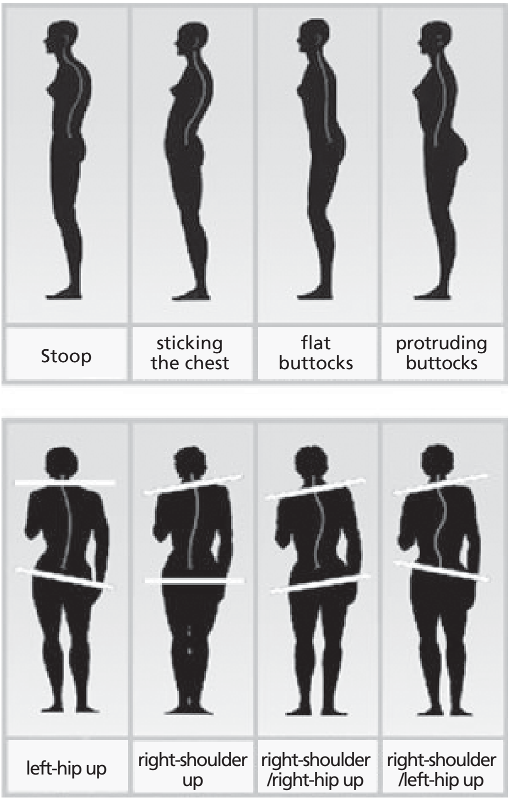


Figure 13.1 The alignment of the spine in relation to the force of gravity has an effect on general health and posture

Chronically distorted posture is normally accompanied by some form of ill-health. Bad posture can manifest itself in a variety of ways. Some of the more common signs of incorrect postural alignment include the following: ***(Refer to Figure 13.1)***

- Protruding abdomen
- Hyperextended knees
- Rounded or uneven shoulders
- Curved spine
- Sunken chest
- Unusually flat back
- Swayed back
- Uneven hips
- Neck craned too far forward
- Chin thrust out

When we look at people's posture at the plumbline, it is easy to understand why the force of gravity is considered one of the most important factors involved in health.

Everything a person does is directly transmitted to his/her centre of gravity, but it is only when the body exceeds what is called its *elastic limit*, that this becomes problematic. (The elastic limit is that point from beyond which the body will not naturally return to its normal position of rest). Suppose someone receives a sudden jerk to the neck; if this trauma exceeds the elastic limit of the body (as in whiplash injury) then, in the long run, destructive change will be reflected at the centre of gravity at the lumbo-sacral articulation.

Damage from accidents, injuries and strains of all sorts become concentrated here and hence it is common for people who do heavy work to complain more of trouble in the lower back than in any part of the body.

The natural centre of gravity of the body as a whole is roughly one inch in front of the centre of gravity of the sacrum itself. The weight of the body acts down through the body's centre of gravity. To compensate for this (and to allow us to stand), another force, equal and opposite, must act up through the legs into the sacrum and its centre of gravity. It is the articulation between these two centres of gravity, called the *loose link*, which actually enables us to move, walk and jump smoothly, without jarring and harming the spine in the process. The loose link can be seen as an evolutionary solution to the challenge of erect but mobile posture.

While this mechanism allows the body a remarkable degree of flexibility, it also entails a specific associated vulnerability. It is a fact that no structure can be said to be distorted without its natural centre of gravity being dislocated, and any dislocation of the body's optimum centre of gravity will disrupt the loose link in its balancing role.

The spinal column houses not only sensory and motor nervous tissue, but also the autonomic nervous system which serves all the organs of the body. This suggests that the consequence of the misalignment of the body at the centre of gravity can have knock-on effects on the workings of virtually any organ or system and thus on health in general.

For many years it was widely held that the lowest lumbar region is the area most in need of treatment. However, it is the adjustment at the sacrum which is actually of primary significance. The sacrum (literally "the sacred bone") is a peculiarly significant, and thus a vulnerable part of the human body. Being placed as it is at the centre of the skeletal structure, and acutely subjected to the force of gravity, it is prone to displacement by prolonged strain and by both physical and emotional pressures.

SPACE AND GRAVITY

When the body is not under the force of gravity, the body and all its systems especially the brain, lose their function significantly. Muscles break down as the result of catabolism, and the spine starts to lose its curvature. This can be seen in the case of astronauts. Reduced gravity reduces stimulation and nerve input to the brain, thus reducing its function causing "Space Dyslexia". A similar pattern has been identified in individuals with ADHD and poor cognitive function. This pattern is also observed in extended bed rest.[3,4]

BRAIN PLASTICITY AND MOVEMENT (MUSCULAR ACTIVITY)

When the brain of humans is compared to that of other mammals, the greatest growth of brain occurs after birth, compared with other mammals. Humans also take the longest to stand erect and walk on two legs. Standing erect allows greater brain stimulation due to greater stimulation of joint and muscle mechanoreceptors by the force of gravity. Increased brain activation by gravity allows greater control over the muscle movements and the ability to execute complex goal oriented movements, leading to greater interaction with the environment and hence greater adaptability and brain plasticity.

It is interesting to note that the areas of the brain involved in movement such as: Cerebellum, Basal Ganglion, Thalamus and prefrontal cortex, are also involved in the cognition and integration of emotions. These areas have motor and non-motor function which work together to modulate reasoning, emotional behaviour and movement.

The driving force behind the mechanics of the skeletal system, from micro motion of cranial bones, facial bones, pelvic bones, sacral bones and bones in the foot, to maintaining the spinal curvature, foot arch, diaphragmatic motion in respiration and movement of blood and lymph, is muscular activity. These muscular activities pattern themselves during the development of primitive reflex (fixed action pattern) development as they adapt to gravity. Cerebellum, vestibular system, limbic (Basal ganglion, Thalamus,) and the prefrontal cortex becomes the control centre of these movement patterns, driven by the amount of stress placed upon them (chemically, structurally), as well as emotional state of the individual.

These fixed motor patterns give rise to more goal oriented movements and proper development of the neocortex. As the complexity of these patterns develops through using various combinations of movements, the abstract thinking and consciousness start to emerge. ***(Refer to Chapter 3)***

Final manifestation of every thought generated within our nervous system is a single muscular contraction to either respond (planned action requiring focus controlled by frontal lobe) or to react for the purpose of survival.

Cognitive function arises from the internalization of movement. Movement is a series of short term predicted movements controlled by higher brain centres. For movement prediction to be efficient, the brain has to process and compare all sensory input and create an image of the world (premotor image) before initiating a specific movement. This premotor image depends on the pre-existing neuro-reflexes evolved by the brain during its development. These neuro-reflexes are pre-programmed fixed action pattern recognition centres in the brain stem and spinal cord. These fixed action patterns are stereotyped, allowing collective use of a series of muscles to reduce the demand on the brain to individually use muscles to perform movement. **This development reduces the need for sleep as well as the development of a larger brain.**

Basal ganglion, Inferior olive and cerebellum, play an important role in coordination of movement and fixed action pattern. When movement is coordinated, it does not overload the nervous system.

A simple movement such as reaching for a carton of milk requires 10-15 combination of muscle contraction and countless decisions per second. This places a lot of burden on the brain and thus can reduce its efficiency. Fixed action pattern evolved to reduce the choices and decisions of the nervous system, thus increasing the organism's survivability.

To overcome this complexity and to reduce the work overload of the nervous system, the brain creates a series of smaller pulsatile and rhythmic movements of 8-13 Hz known as physiological tremor which is present during activity or at rest. This oscillation keeps the cells closer to action potential or excitation and its function is maintained by calcium /potassium ion channels.

Emotions can also be considered as a form of fixed action pattern and are considered premotor in nature. Just as muscle tone serves as a base platform for muscle movement, emotions are premotor platforms which either drive or cause deterrence of our actions. For instance, children with autistic spectrum disorders and attention deficit hyperactive disorders exhibit stereotyped patterns of movements which could be as the result of uninhibited fixed action patterns, resembling hyperkinetic type movements.[6,7]

Emotions are linked to the motor aspects of fixed action pattern through their access to amygdala, hypothalamus and their associated connection to brain stem.

GLOBAL INTEGRATION OF MOVEMENT AND BRAIN HIGHER CENTRES

Activation is the ability of nerve cells to get excited and summate within the brain enough to cause action potential and the firing of nerve cells. As discussed previously, gravity is the primary means of excitation prenatally, and after birth, through development of primitive reflexes. Gravity activates muscle spindle cells which activate brain function which causes a motor response. As the child creates an awareness of his/her environment, senses start to develop which contribute to activation. At this stage we have gravity and sensory input to the brain. The brain has a self wiring mechanism. Once consciousness evolves, it can maintain its own activation with minimal gravitational and sensory input. However, this is not the option of choice for the brain and is inefficient as it is only used in times of need such as severe trauma, spinal cord injury or coma. During this time it allows the brain to maintain some muscle tone for the integrity of its function until the trauma or insult has been resolved.

PRIMITIVE REFLEXES

Crawl Reflex

Grasp Reflex

Step Reflex

Tonic Neck Reflex

The primitive reflexes are a group of behavioural motor responses which are found in normal early development, and are subsequently inhibited but may be released from inhibition by cerebral, usually frontal, damage. I.e damage to frontal lobes or neocortex can result in the inappropriate expression of a primitive reflex. The inappropriate expression of some reflexes can have an adverse affect on sleep quality or contribute to sleep apnoea, snoring or open mouth breathing.

Primitive reflexes are:
Survival reflexes that occur sequentially in the first few weeks of foetal development.
Automatic, stereotyped movements, directed by a very primitive part of the brain (brain stem).
Executed without involvement of higher levels of the brain (the cortex).
Ideally short lived and as each fulfils its function; it is replaced by more sophisticated structures (Postural Reflexes) which are controlled by the cortex.
Retained if they do not fulfil their function.
Considered aberrant and evidence of an immaturity within the CNS if present beyond their time.

The postural reflexes support control of balance, posture and movement in a gravity-based environment. Postural reflex development is mirrored in the infant's increasing ability to control its body, posture and movements.

Some children fail to gain this control fully in the first year of life and continue to grow up in a reflexive 'no man's land', where traces of the primitive reflexes remain present and the postural reflexes do not develop fully. These children continue to experience difficulty with control of movement affecting: coordination, balance, fine motor skills, and motor development, and associated aspects of learning such as: reading, writing and physical education.

Retained primitive reflexes can also affect a child's sensory perceptions, causing hypersensitivity in some areas and hyposensitivity in others.

Primitive reflexes emerge in utero and are present at birth and normally are inhibited by 6 - 12 months of age. Inhibition of a reflex correlates with control of these reflexes by higher centres of the brain. This allows more complex neural structures to develop, which makes them voluntary.

If these reflexes remain active beyond their time span, they are said to be aberrant, and they represent structural weakness or immaturity within the central nervous system. They can also inhibit development of succeeding reflexes which emerge to enable the child to interact effectively with its environment.

The inability of higher centres to have voluntary control over reflexes results in the over-activation of survival mechanism, thus reducing the integrity of the limbic system and delaying maturity and learning skills.

Specific movement patterns made in the first months of life contain within them a neural circuit that can inhibit these reflexes. If the child does not use these primitive reflexes or makes some of its movements in the incorrect sequence, the primitive reflex may remain active as a result.

After birth, the sense of movement continues through vast and continuous movement patterns from lying, kicking, rolling and sitting, to crawling and creeping on the hands and knees, walking, running, hopping, skipping, swinging, rolling and tumbling. As far as babies are concerned, when they move, the world moves with them and when they stop, the world stands still.

It takes 7-8 years for the balance mechanism, cerebellum and the corpus callosum, to be myelinated. After this time, the most advanced level of balance achieved stays with the individual for the rest of their life. It also indicates that the higher centres of the brain have taken control over the primitive brain.

These reflexes provide the foundation for a mature nervous system. An interruption to the sequence of reflex development results in dysfunction in the vestibular system and the reticular activating system.

Over-stimulation may cause panic disorders and hyperactivity, whereas under-stimulation may contribute to symptoms such as: sudden infant death syndrome, sleep apnoea, epilepsy and seizure-like episodes.

It is interesting to note that hyperactive children, who are allowed to spin for 30 seconds in either direction, show increased attention span for 30 minutes afterwards. A child who cannot stay still, intuitively knows that his/her balance still needs further maturation.[8]

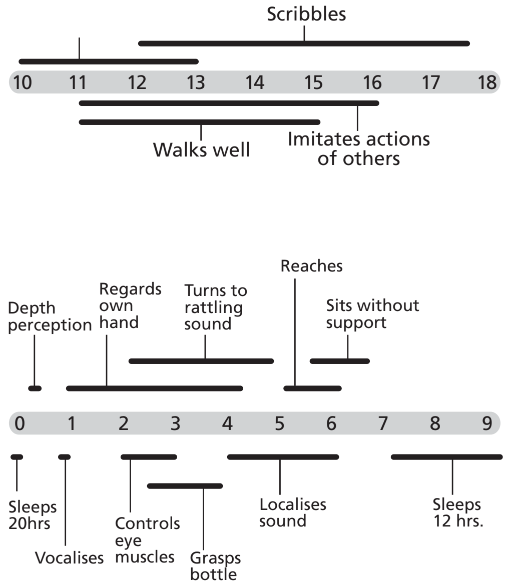


Figure 13.2 Developmental Milestones While there is enormous variation in the timeline of child development, this figure depicts the average age in months for the acquisition of specific abilities. Developmental milestones provide clues about how the brain refines its control over the body, and about the ways that we learn to interact with the world.

PRIMITIVE AND POSTURAL DEVELOPMENT

Children who are born prematurely or through caesarean section are at higher risk of poor development of some primitive reflexes or extinction of primitive reflexes. Because of the extra load in nerve processing to maintain normal postural development, these children will tend to sleep more.[9]

MORO REFLEX OR STARTLE REFLEX

The Moro reflex acts as a baby's primitive fight/flight reaction. It emerges at 9 weeks in utero and is fully present at birth and is usually inhibited between 2-4 months of life. The Moro reflex is an involuntary reaction to threat. Its role within the first month of life is to alert and to arouse in order to attain assistance. It assists in developing the baby's breathing mechanism in utero. It facilitates the first breath at birth.

Moro reflex – The baby extends his/her arms then bends and pulls them in towards their body, accompanied by a brief cry, often triggered by loud sounds or sudden movements.

This reflex is very important for future development of our nervous system. Since it is the first reflex to be activated in response to perceived threat, it thereby initiates the release of stress hormones, adrenaline and cortisol. A properly developed and maintained Moro reflex in a child or adult consists of quick shrugging movement followed by a turn of the head to check for the source of the disturbance. Once identified, the child proceeds with whatever it was previously doing.

PHYSIOLOGICAL RESPONSE TO MORO REFLEX

The physiological aspects of the Moro reflex are as follows:

1. Immediate arousal (Activation of reticular Activating System), followed by rapid inhalation and a pause and a rapid expiration accompanied with a cry.
2. Activation of fight and flight response which triggers the sympathetic nervous system and initiates the release of stress hormones (Initially nor-adrenaline and adrenaline). This increases the rate of breathing, heart rate, blood pressure and perspiration.
3. Continuous rapid breathing leads to poor development of CO2 reflex (the spontaneous inhalation of the upper and lower part of the lungs) because CO2 is blown off. Normally, when the CO2 levels in blood increase, the medulla oblongata (the breathing centre in the brain stem) is stimulated, which then opens the arteries to increase the blood supply to the brain, stimulating deep breathing.

Surprisingly, these symptoms resemble the symptoms of sleep apnoea and snoring which we explored in previous chapters.

Note: Poor CO2 reflex is what makes the Buteyko technique (holding breath and breathing through the nose) an effective treatment for sleep apnoea and asthma.

Ongoing activation of Moro Reflex results in coping in one of two ways:

Withdrawing from difficult situations, difficulty socializing , or

Neither accepting or demonstrating affection or becoming aggressive, highly excitable, over-reactive and dominating.

Other symptoms of compromised Mora Reflex include:

- **Vestibular related problems**
  - Motion sickness, poor balance, poor coordination
  - Poor pupillary reaction and sensitivity to light
  - Difficulty with black print over white paper
  - Hypersensitive to sound
  - Poor Auditory discrimination skills
  - Allergies
  - Lower immunity
  - Asthma
  - Eczema
  - Frequent ear, nose, throat infections
  - Poor stamina
  - Poorly developed CO2 reflex
  - Reactive Hypoglycaemia
- **Psychological symptoms:**
  - Continuous anxiety
  - Mood swings
  - Tense muscle tone
  - Difficult to change
  - Indecisive
  - Insecure

– Hyperactivity
– Hypersensitivity
– Need to control events
– Poor impulse control
– Difficulty accepting criticism
– Low self esteem
– Dependency
– Stimulus bound effect – cannot ignore peripheral stimuli to focus attention on one thing – has to pay attention to everything
– Sensory overload
– Anxiety – particularly anticipation anxiety

It is believed that the Moro reflex creates the basic foundation for life, which is to feel safe, and it is essential for the child's survival for the rest of his/her life.

THE PALMAR REFLEX: THE INFANT GRASP REFLEX

This reflex emerges at 11 weeks in utero, is fully present at birth and usually inhibited by 2-3 months of life.

A light touch or pressure to the palm of the hand will result in the closure of the fingers. The Palmar reflex can also be elicited by sucking movement (Babkin response).

Both the hand and mouth movements are important for feeding throughout life and are a source of exploration and expression.

The future consequences of improperly maintained Palmar Reflex are:

- Poor speech
- Poor muscle development around the lips
- Poor pencil grip when writing
- Poor manual dexterity
- Movement of mouth while writing.

Other symptoms such as mouth breathing and snoring have been observed in children with a poorly developed Palmar reflex.

ASYMETRICAL TONIC NECK REFLEX (ATNR)

The asymmetrical tonic neck reflex is activated as a result of turning the head to one side. As the head is turned, the arm and leg on the same side will extend, while the opposite limbs bend. The reflex should be inhibited by six months of age in the waking state.

This reflex emerges at 18 weeks in utero. It is fully present at birth and becomes under the control of higher centers at about 6 months of age.

During uterine life, the asymmetrical tonic neck reflex should facilitate movement (the kick), develop muscle tone, provide vestibular stimulation and assist the birth process.

The ATNR in utero provides continuous motion which stimulates the balance mechanism and increases neural connections.

During the second stage of labor, the baby should help the delivery using a screw like motion down the birth canal in rhythm with the mother's contraction. Normally, the ATNR in utero provides continuous motion, which stimulates the balance mechanism and increases neural connections.

Normally, as the baby is being born, the doctor or midwife turns the baby's head gently from one side to the other, activating the reflex further. Children who are born with forceps, vontouse or caesarian birth, are at risk of developmental delays.

If the asymmetrical tonic neck reflex remains active in a child at a later age, it can affect:

- Hand-eye coordination – difficulties such as the ability to control the arm and hand when writing or difficulty in crawling or using excessive pressure when writing.

- The ability to cross the vertical midline. For example, a right-handed child may find it difficult to write on the left side of the page.
- Discrepancy between oral and written performance i.e. showing weakness expressing ideas in written form.
- Development of lateral eye movements, such as visual tracking, which is necessary for reading and writing. I.e. eye tracking problems.
- Control of automatic balance.
- Bilateral integration – differentiated and integrated use of the two sides of the body. I.e. Difficulty crossing the midline (clumsy when playing basketball or football).
- Continued cross laterality or ambiguity of laterality above eight years of age. I.e. walking with the left hand forward as his/her left foot moves forward (proper cross lateral movement is swinging opposite arm and leg) or slow in reading as the eyes cannot cross the midline to follow the word across the page.

Impairment of this reflex is involved in a majority of cases where sleep is an issue; especially snoring and sleep apnoea.

ROOTING REFLEX

This reflex facilitates sucking and swallowing. A light touch of the cheek or stimulation of the mouth will cause the baby to turn the head towards the stimulus and open the mouth with extended tongue in preparation of sucking.

Sucking and swallowing are vital during the early stages of feeding and can weaken if the baby is not rewarded for his/her attempts for the first couple of hours after birth.

A compromised Rooting Reflex is associated with:

- Poor speech articulation
- Prolonged thumb sucking
- Messy eating
- Dribbling
- Oversensitivity around lips and mouth
- Possible development of a high palate which increases the risk of sleep apnoea

The development of normal swallowing and of normal coordination between respiration and oral function are essential for the development of speech.

SPINAL GALANT REFLEX

It is initiated by placing the baby in a prone position and stimulating the lumbar region of the back which results in hip flexion to 45 degrees towards the side of stimulation. The strength of the reflex should be equal on both sides.

This reflex is the primitive conductor of sound in utero within the aquatic environment, helping the foetus to feel sound and assists sound vibration to travel up the spinal column.

It aids in the birth process, along with rotational movement of Asymmetrical Tonic Neck Reflex.

Compromised Spinal Galant Reflex or its persistence after 9 months may result in:

- An inability to sit still
- Poor posture
- Poor concentration and attention
- Bed wetting,
- Poor short term memory

- Hip rotation to one side when walking
- The development of scoliosis (curvature) of the spine

A high percentage of adults with Irritable bowl syndrome exhibit problems with the Spinal Galant Reflex.

TONIC LABYRINTHINE REFLEX (TLR)

Inhibition of the tonic labyrinthine reflex is a gradual process involving the maturation of other systems. It should be completed by three and a half years of age. If it persists beyond this time, it is sometimes associated with:

- Postural problems, specifically hyper- or hypotonus (muscle tone)
- Tendency to walk on the toes
- Poor balance
- Motion sickness
- Orientation and spatial difficulties
- Oculo-motor problems – affecting reading
- Visual-perceptual problems – affecting reading and writing
- Dislike of Physical Education (PE)

1- TONIC LABYRINTHINE REFLEX (TLR) BACKWARDS

The **tonic labyrinthine reflex** (TLR) is initiated by tilting the baby's head back while lying on the back. It causes the back to stiffen and even arch backwards, causes the legs to straighten, stiffen, and push together, causes the toes to point, causes the arms to bend at the elbows and wrists, and causes the hands to become fisted or the fingers to curl. The presence of this reflex beyond the newborn stage is also referred to as *abnormal extension pattern* or *extensor tone*.

Emerges: at birth

Inhibited: Gradually inhibited from 6 weeks to 3 years of age.

Involved in the simultaneous development of:- postural reflexes, symmetrical tonic neck reflex and the Landau reflex.

The Tonic Labyrinthine Reflex assist the new born to make the smooth transition from the aqueous environment, where there is minimal gravity, to a gravity-based environment using the vestibular apparatus.

This reflex assists the development of the head position in space and the control of its movement in relation to the rest of the body and gravity. As the name implies, this reflex influences the distribution of muscle tone throughout the body.

This reflex gives the body a point of reference to allow the body to know where it is in space and discriminate the left from right, up from down and judge distance, depth and velocity.

This reflex is important for our survival in a gravity-based environment. When astronauts are placed in a gravity-free environment, they start to write from right to left, write in reverse and mirror writing; functions categorized as a disability. Proper functioning of Labyrinthine reflex leads to development of head righting reflex which allows us to gain control of the head over the body. If head control is lacking, eye functioning will also be affected since the eyes and the vestibular system operate from the same neuro-circuitry in the brain (vestibular nuclei).

Compromised Tonic Labyrinthine Reflex Backward will result in:

- Poor posture
- Walking on toes
- Poor coordination and balance
- Motion sickness
- Poor sequencing and organizational skills
- Visual and Spatial perception difficulty
- Stiff jerky movements

2-TONIC LABYRINTHINE REFLEX (TLR) FORWARD

Emerges: in utero – flexus habitus (The actual fetal position in utero)

Birth: Present

Inhibited: Approximately 4 months of life

Compromised Tonic Labyrinthine Reflex Forwards will result in:

- Poor posture
- Stoop Hypotonus (poor muscle tone)
- Poor sense of balance.
- Car sickness
- Dislike of sporting activities.
- Spatial problems
- Poor sequencing skills
- Poor sense of time
- Visual perceptual difficulties

SYMMETRICAL TONIC NECK REFLEX

1. Forward

When the child is in the quadruped position, flexion of the head causes the arms to bend and the legs to extend.

Emerges: 6-9 months of life
Inhibited: 9-11 months of life

2. Backward

Head extension causes the legs to flex and the arms to straighten.

Emerges: 6-9 months of life
Inhibited: 9-11 months of life

Compromised Symmetrical Tonic Neck Reflex – Flexion & Extension will result in:

- Poor Posture
- Lies on desk when writing.

- Poor eye-hand coordination
- Problems with refocusing from far to near distance
- Clumsy child syndrome
- Tendency to slump when sitting at the desk
- Ape-like walk

Proper development of labyrinthine followed by symmetrical tonic reflex and head righting reflex, will lead to proper crawling stimulating the eyes to move across the midline while the child crawls, and head flexion and extension will allow the child to focus the eyes from far to near.

These **Vestibular based reflexes** can extend to adult life and create more postural and behavioural difficulties accompanied by biochemical and pathological consequences such as:

- Chronic Fatigue syndrome
- Allergies
- Fibromyalgia
- Upper respiratory breathing disorders
- Poor immune function
- Autoimmune disorders
- Weight gain
- Depression
- Diabetes

Possible causes of poor Vestibular function:

- Premature birth
- Exposure to excessive movement or invasive sounds as a foetus (fetus) or infant such as loud music and/or parents arguing.
- Neglect (little handling and moving) during infancy
- Repeated ear infections or a severe ear infection
- Tubes (grommets) having been inserted in the ears to drain excessive fluids
- Excessive use of infant seat, jumper, swing and/or playpen, thus restricting or limiting natural movement.
- Excessive watching of things spin, or excessive spinning of self
- Falls, Forceps delivery, head injury, flexion and extension injury (whiplash), as a passenger in car accident.
- Nutritional deficiencies (Zinc, Magnesium, Iron, selenium)
- Virus and bacterial infection
- Heavy metal toxicity (Mercury, Aluminum, Lead)
- Congenital deformities
- History of traumatic brain injury, shaken child syndrome, ear cuffing.

Symptoms of poor Vestibular system (in adults or children):

- Avoidance of movement except as absolutely necessary
- Avoidance of head movement
- Head banging
- Motion sickness (car, boat, airplane)
- Avoidance of merry-go-rounds
- Dizziness or nausea caused by watching things move
- Inability to read or write in cursive
- Hearing problems
- Inability to sustain listening without moving or rocking
- Problem with balance (static or moving) and/or vertigo
- Difficulty walking on uneven ground
- Tooth Grinding while asleep
- Clicking Jaw
- Ongoing neck and back Pain
- Need to move fast
- Phobia, Anxiety
- Desire to control events
- Hyperactivity
- Slow reader
- Snoring
- Sleep Apnoea
- Depression

THE IMPORTANCE OF THE VESTIBULAR SYSTEM

The vestibular system has been identified in number of clinical syndromes, including: circadian dysfunction, sleep–wake disorders, anxiety disorders, space-adaptation syndrome, and autonomic dysfunction.

There exists abundant anatomical evidence that the vestibular nuclei project to numerous brainstem autonomic nuclei that, in turn, project to the hypothalamus. Moreover, a number of these nuclei have been shown to influence homeostatic and circadian function. Such nuclei include: the parabrachial, caudal raphe nuclei, solitary nucleus, and the locus coeruleus. In addition, some brainstem information may be routed and processed by limbic structures, e.g., amygdala and infra-limbic cortex, before reaching the hypothalamus. The potential involvement of the limbic system may influence the "affect" of the individual. This also has an influence on hypothalamic function. A putative association exists between the vestibular dysfunction and affective disorders, e.g., anxiety or agoraphobia. The neuro-vestibular system can also influence changes in body composition, particularly the mobilization and utilization of fat.[5]

The neuronal circuits responsible for circadian rhythm genesis, thermal control, feeding, and autonomic function, are located, to a large extent, in the hypothalamus. The hypothalamus ensures normal (e.g., feeding, body metabolism, thermoregulation, cardiovascular, fluid balance) and adaptive (e.g., stress, exercise) homeostasis, by altering a variety of neural and endocrine effector mechanisms, including the balance between sympathetic and parasympathetic outflow.

Vestibular System and Neural/Muscular Reflexes

Proper development of survival-based neural reflexes starts with the vestibular system.

The vestibular system monitors motor development, through control of reflexes to core muscle activation. That is, activity that involves:- neck muscles, arms and legs, leading to rolling over sitting, crawling and walking and motor exploration. All these hardwired and learnt reflexes support future development of hearing, tactile, smell, taste and finally seeing. This also enables rich sensory activation and future development of emotions memory and cognition.

These reflexes are automatic and are controlled by the brain stem and cerebellum.

Neuro-vestibular System or Inertial Sensors

Three of the main functions of the vestibular system are: to contribute to gaze stabilization, the sensation of orientation or movement and postural control.***(See:http://paperairplane.mit.edu/16.423J/Space/SBE/neurovestibular/NeuroVestibular/7_Glossary/Glossary.html – GlossV8)***. The vestibular apparatus is responsible for balance. It consists of three semicircular canals, which detect movements of the head, and the utriculus and sacculus, which detect the position of the head. ***(Refer to Figure 13. 4)***

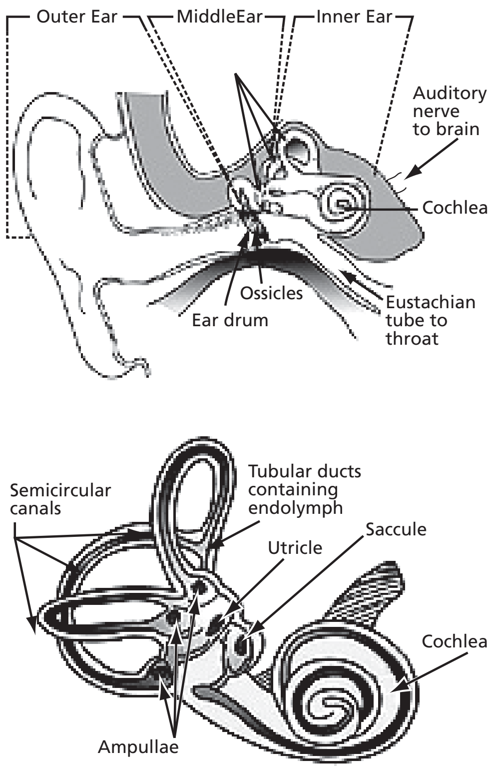


Figure 13.4. Semicircular canals, utricles, saccules are interconnected, fluid-filled sacs and ducts that are enclosed within the petrous bone. This "membranous labyrinth" is filled with "endolymph"; a fluid that is likened to intracellular fluid. The space around the endolymph-laden structures contains "perilymph", likened to cerebral spinal fluid.

The first sensory system to fully develop by six months after conception is the vestibular system, which controls the sense of movement and balance.

This system is the sensory system considered to have the most important influence on the other sensory systems and on the ability to function in everyday life. Directly or indirectly, the vestibular system influences nearly everything we do. It is the unifying system in our brain that modifies and coordinates information received from other systems. The vestibular system functions like a traffic cop, telling each sensation "where and when it should go or stop."

The vestibular system influences the autonomic nervous system. This explains why individuals may have problems breathing or may develop nausea or irregular heart rates when the system is overwhelmed.

The vestibular system is located in the inner ear and responds to movement in three planes of movement: vertically up and down, horizontally left and right, and over the top of the head from left shoulder to right shoulder. These are the same references for air flight; pitch (vertical), yaw (horizontal), and roll (over the top).

Each time the head moves, there is corresponding movement of fluid in the vestibular system of each ear. This movement of fluid allows each ear to sense how far the head has moved and with what velocity.

Vestibular nuclei reside in the mid and lower pons and the medulla, and are composed of: the superior, lateral, inferior, and medial nuclei. They send most of their output to the spinal cord and to the extra-ocular muscles. There are two vestibule-spinal tracts, lateral and medial. The lateral vestibular spinal tract (LVST) is the much bigger tract in terms of number of axons. It descends down the length of the cord and excites antigravity muscles. Its function is to hold the body upright and prevent collapse. Its biggest input is from the cerebellum. For example, if the floor under us suddenly shifts backwards, tilting the body forward, the action of the LVST is to contract the gastrocnemius (stabilize the ankle) and hamstrings (stabilize the knee). A patient with cerebellar damage might be unable to do this.

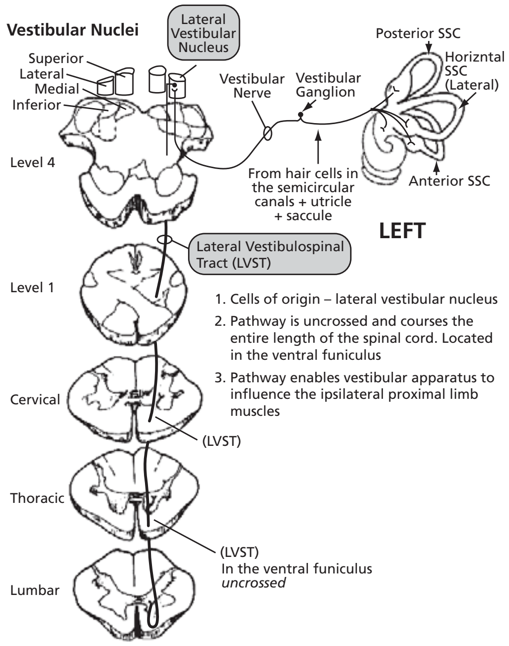


Figure 13.5. Left lateral vestibulospinal tract. The increased activity in the left vestibular nuclei can affect the body musculature via the left lateral vestibulospinal tract. This will result in increased activity in the LEFT arm and leg in order to right ourselves after slipping.

Medial vestibulospinal tract (MVST) has a smaller number of axons and descends only to the cervical spinal cord. The function of MVST is to stabilize the head in space when the body is moving (for example, when we are walking around), and to stabilize the eyes and maintain gaze during head movements.

Other functions directly governed by the vestibular system include:

(1 Auditory functions via the vestibulo-cochlear nerve (the vestibulo-cochlear nerve carries information to the brain from the inner ear).

(2) Visual functions

(3) Muscle tone, balance and proprioception

(4) Sleep

Smell, taste and touch, are the only three modalities of human processing that are relatively unaffected by vestibular function.

The vestibular system serves to regulate posture and to coordinate eye and head movements. For example, to keep the head upright and define the vertical, the vestibular system acts on the neck muscles using input from both the visual system and from the semicircular canals. It uses information from both of these sources, as well as proprioception, to excite the antigravity muscles to hold the body upright. If you were to spin yourself around until you felt dizzy and then try to stand still, you will stagger. This is because the vestibulospinal system is being over-stimulated. Finally, it plays a dominant role in stabilizing the eyes in space when the head is moving. It gives you the ability to keep looking at an object (maintain gaze) even though your head may be rotating.

Vestibular System and Breathing

Changes in posture can affect the resting length of the diaphragm, which is corrected through increases in both diaphragm and abdominal muscle activity. Furthermore, postural alterations can diminish airway patency, which must be compensated for through increases in firing of upper airway muscles.

Recent evidence has shown that the vestibular system participates in adjusting the activity of both upper airway muscles and respiratory pump muscles during movement and changes in body position.

The vestibular system, by controlling respiration, enables rapid adjustments in ventilation such that the oxygen demands of the body are continually matched during movement and exercise.[10]

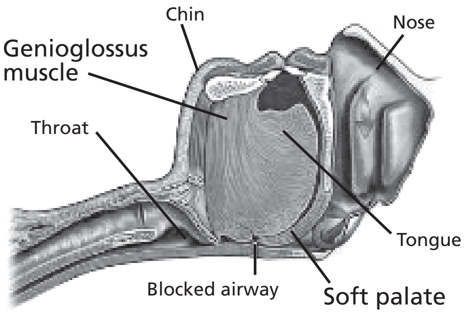
During quiet breathing, the muscle predominantly involved in respiration is the diaphragm, although the intercostals and abdominal muscles also participate to a lesser degree. However, if oxygen demand is enhanced, as during exercise, the role of the abdominal and intercostal muscles in ventilation increases dramatically.[11]

Ventilatory muscles also have other functions, including eliciting protective reflexes, such as:

- sneezing and vomiting
- generating postural stability and voluntary movement producing vocalization while maintaining stable blood levels of oxygen and carbon dioxide.

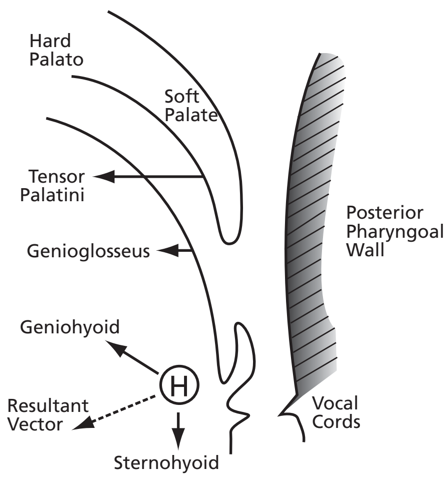
In addition to the pump muscles (that move air into and out of the lungs), muscles in the upper airway such as Genioglossus, also contract in a coordinated fashion during respiration. Some of these muscles are active during inspiration and serve to maintain airway patency. [12]

THE ROLE OF THE TONGUE IN SLEEP



The genioglossus muscle comprises much of the body of the tongue and is attached to the inside front of the jawbone (see illustration). With normal muscle tone, the genioglossus holds the tongue forward in the mouth when one is awake and is the muscle used to stick one's tongue out.

Poor muscle tone results in the tongue not staying forward as may occur during REM sleep, thus allowing the tongue to fall back and block the airway.



A depiction of the action of various muscles on pharyngeal structures. The tensor palatini moves the soft palate ventrally. The genioglossus acts to displace the tongue ventrally. The geniohyoid and sternohyoid act on the hyoid bone (H) to move it.

Figure 13.6. The Position of the tongue in relation to sleep disordered breathing and normal function.

Control of the size of the upper airway and stiffness of the walls depends on the relative contraction of a host of paired muscles known as the *pharyngeal dilator muscles* ***(See Table 13.1)***. Contraction of these muscles promotes ventral movement of the soft palate, mandible, tongue, and hyoid bone as shown in **Figure 13.6 and Table 13.1.** It is generally accepted that inspiratory motor output to the muscles of the pharynx and related structures, stiffens the pharynx and enlarges its lumen. The activity of the pharyngeal muscles is highly dependent upon a variety of factors within the central nervous system, particularly at the brain stem level. Wakefulness conveys a supervisory function that ensures airway patency. Sleep onset and pharmacologic agents that depress the brain stem respiratory network interact with the dilating effects produced by the musculature, thus implicating the nervous system as a secondary contributor to the development of obstructive sleep apnoea and hypopnoea.[13]

Table 13.1. The Muscles of the Pharynx and Their Actions

Muscle	Action
Digastricus	Elevates hyoid, depresses mandible
Genioglossus	Protrudes tongue (inf. fibers), depresses tongue (mid. fibers)
Geniohyoid	Elevates hyoid, depresses mandible
Levator veli palatini	Elevates soft palate
Musculus uvulae	Shortens the uvula
Palatoglossus	Elevates and retracts the tongue
Palatopharyngeus	Elevates larynx
Salpingopharyngeus	Elevates larynx
Styloglossus	Retracts and elevates tongue
Stylohyoid	Elevates and retracts hyoid
Stylopharyngeus	Elevates larynx
Tenor veli palatini	Opens auditory tube, tenses soft palate

When the body takes a breath, the chest expands and the diaphragm lowers, creating a vacuum that pulls in air through the airway i.e. a negative air way pressure. In obstructive apnoea, that vacuum can pull the soft palate, tongue and uvula against the back of the throat, blocking the airway, especially when the airway is narrow or compromised. During sleep, body muscles completely relax, including the genioglossus. When this happens, the tongue can fall back (especially if the person is sleeping on their back) and block the airway; resulting in obstructive apnoea. ***(Refer to Figure 13.6)***

Therefore, the genioglossus muscles must be more active during these postural changes in order to maintain airway patency. Failure of this response in humans produces snoring and obstructive sleep apnoea.[14,15]

At the wake-sleep transition, there are moderate reductions in mean genioglossus (GG) and Tensor Palatini (T) muscle activity. During stable NREM and REM sleep, both GG and TP muscle activity are lower than during relaxed wakefulness. Compared with sleep onset, there is a further decrease in the activity of TP during stable NREM and REM sleep, but for GG only during REM sleep. Thus, wakefulness has an important independent effect on upper airway dilator muscle activity that is unlikely to be mediated through the respiratory or mechanical control systems. The initial reduction in upper airway muscle activity at sleep onset is due to loss of a ''wakefulness'' stimulus rather than to loss of responsiveness to negative pressure.[16]

Vestibular system contributes to regulating genioglossus firing.[17]

During wakefulness, premenopausal women have higher genioglossal muscle activity compared with age-matched men, possibly due to progesterone. This may explain the low rates of sleep apnoea in females.[18]

THE ROLE OF VESTIBULAR SYSTEM AND SLEEP

Phylogenetically ancient brain areas use 'primal' gravity-dependent coordinate reflexes and stimuli parameters to relay and process information about self and environment. This is achieved using Vestibular system and its subsystems mentioned. It has been proposed that the REM sleep could have served as a phylogenetically older form of wakefulness, wherein the brain uses a gravitoinertial-centred reference frame and an internal self-object model to evaluate and integrate inputs from several sensory systems.[19]

Infants spend a great deal of time in REM sleep; that may be a way to get their motor system prepared for standing, walking, and running. Many researchers believe the purpose of sleep is to promote memory and consolidation of what is learned during the day. Dreams may involve memories of vestibular learning; they are filled with continual movement such as: running, flying, spinning, twitching, and turning.

Astronauts who float in space for a week or more need visual cues to find their way around after they first land. Stickgold [20] tells about an astronaut, recently returned to gravity, who got into bed one night without turning off the light. He feared getting up to turn it out, because he was not sure he could walk in the dark. Even crawling might not work; insecurity about knowing up from down could cause him to flop over on his side. He had to call someone from his bedside telephone to come over and turn off the light.

"REM sleep promotes changes in the brain that help astronauts adapt their motor system, particularly balance, to the near absence of gravity," says J. Allan Hobson, professor of psychiatry. "There is evidence of a feedback mechanism wherein adaptation to weightlessness increases REM sleep and dreaming, which in turn may enhance balance, orientation, and movement." Optimal human performance depends upon integrated sensorimotor and cognitive functions; both of which are known to be exquisitely sensitive to loss of sleep. Changes in sleep and dreaming are associated with the vestibular adaptation that occurs with adaptation to microgravity, and readaptation to gravity-based conditions.[20]

THE ROLE OF OTHER SENSES

Essentially we use five systems to determine where our bodies are in relation to the environment and where various parts of our bodies are in relation to one another and gravity:

1. The information received by the brain from the inner ear regarding the position of our heads, the pull of gravity, the speed and acceleration of our movement.
2. The interpretation of messages received by our eyes about both space and our position and posture.
3. The assorted information received by our brain from tactile, kinesthetic and proprioceptive sites located throughout the body.
4. The messages received by the brain through smell; a sense on which we unconsciously rely to discern direction and distance from objects and events in our environment.
5 The interpretation of the messages we have received through hearing, which also helps us orient to specific objects and events in our environment.

If any of these functions or the above systems are irregular, there will be a diminished sense of body-in-space or place, greater reliance on another system (such as vision) to compensate, which in turn causes us to use our eyes inefficiently for broader or higher level visual functions.

HEARING (AUDITORY)

Our hearing faculty is the reception and transmission of energy through motion and vibration. Sound travels through the whole body via bone and therefore sound discrimination skills are very valuable in all aspects of learning.

- Myelination occurs between 24-28 weeks in the utero.
- The foetus responds to the auditory stimuli within the utero and outside as well.
- Hearing is best developed within the first 3 years of life.
- Frequent ear, nose and throat infections in early childhood result in hearing loss and poor auditory discrimination skills.

Auditory problems can cause:

- Short term attention span
- Distractibility
- Hypersensitivity to sounds
- Hesitant speech

– Poor reading aloud
– Poor spelling
– Reversal of letters
– Inability to sing in tune.

Turning to Sound Reflex

Similarly, a child first turning to observe a sound indicates the maturation of a number of different processes. In the first months, there is an assortment of maps concurrently developing in the brain that are independent of one another including: a visual map, an auditory map, and a somato-sensory, or tactile map. Only after maturation and integration of these processes can a child hear a sound, and by connecting the visual, auditory, and somato-sensory maps, locate its origin.

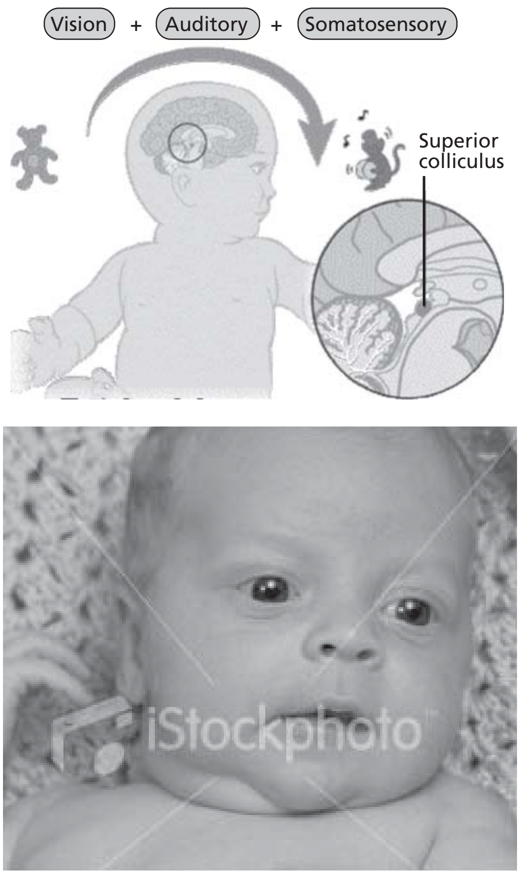


Figure 13.7 Orienting the Head to Sound Turning the gaze to the source of a sound requires a combination of information from vision, audition, and somato-sensation. Sensory maps of these systems are integrated in the superior colliculus; a structure that calculates where the sound is in space and how far to move the head to find the sound source.

When experience brings these maps into sync, sometime between 2 and 4 months, the sound sets off an extraordinary series of events, all orchestrated by the superior colliculus; the part of the brain responsible for orienting the head.

Proprioception or Touch

Proprioception refers to the brain's unconscious sense of body-in-space.

Proprioception differs from kinesthesia in that kinesthesia is the sense of relative muscle, joint and tendon position in specific situations.

Kinesthetic memory involves learning these positions and the sequence of shifts in these positions for repeated movements (such as gymnastics).

Proprioception is a dynamic sense, allowing continuous accommodations and adaptations to a shifting environment (such as in dance, or moving through a crowded room).

The Proprioceptive System is part of the vestibular system, where special receptors in muscles and joints travel quickly from the cerebellum to enhance tone and joint stability.

Proprioceptive weaknesses and irregularities:

- A need as a baby to be held, swaddled, snuggled
- Unusual need to have physical contact with another person; clinging.
- Hysteria over hair washing or pulling tee-shirts over the head
- Avoidance of eyes closed activities (such as Pin the Tail on the Donkey [e.g. Bates' palming exercise, sunglasses or tinted glasses])
- Discomfort or disorientation in the shower
- Difficulty falling asleep and staying asleep
- Sleep walking
- Falling out of bed
- Feeling as if he/she is floating in space or tipping in space while in bed

- Extreme restlessness while sleeping/restless leg syndrome
- Difficulty getting up and moving after sleep
- Need for heavy covers or clothing or a back pack to feel grounded
- Need to have the light on to sleep
- Avoidance of team sports
- Aversion to crowds
- Preference for and greater skill in swimming than in other sports
- Clumsiness, tripping over own feet, bumping into things
- Swinging between pieces of furniture
- Unusual degree of stretching and yawning
- Difficulty grasping mathematical concepts
- Inability to accept physical (and social) boundaries

Visual Reflexes

Vision allows the brain to orient the location of the head or body by sight.

- When the head turns to the left, the **eyes typically follow around to the left.**
- Once the **eyes settle on a target**, the brain uses this information as a reference for the balance system.

Conditions that reduce **visual acuity** will affect the ability of the eyes to locate an appropriate visual reference. Improper eyeglass prescription, glare from reflective surface, eye disease such as glaucoma and cataracts can reduce the accuracy of one's visual acuity and impair your reference for proper balance.

The proper development of primitive reflexes ensure proper neurological behaviour and patterns of movement necessary to support the structure and the function of main survival instincts:- Fight/ Flight, Digestion, sleep, alertness and Reproduction.

These reflexes come under control of higher centres of the brain (cortex) later on in life.

SUMMARY

The extinction of primitive reflexes is important in maintaining brain energy efficiency. Their continual presence after birth, results in an increase in energy and processing demand, which increases the need for sleep. Furthermore, specific primitive reflexes such as the Moro reflex, if not extinguished or taken over by higher brain functions, increase the risk of sleep disordered breathing later in life.

Further Reading

1. **Monk TH, Kennedy KS, Rose LR, Linenger JM.**Decreased human circadian pacemaker influence after 100 days in space: a case study. Psychosom Med. 2001 Nov-Dec;63(6):881-5.
2. **Mallis MM, DeRoshia CW.** Circadian rhythms, sleep, and performance in space. Aviat Space Environ Med. 2005 Jun;76(6 Suppl):B94-107
3. **Pitcher TM, Piek JP, Hay DA.** Fine and gross motor ability in males with ADHD. Dev Med Child Neurol. 2003 Aug;45(8):525-35.
4. **Foulder-Hughes LA, Cooke RW.** Motor, cognitive, and behavioural disorders in children born very preterm. Dev Med Child Neurol. 2003 Feb;45(2):97-103.
5. Fuller PM, Jones TA, Jones SM, Fuller CA. **Neurovestibular modulation of circadian and homeostatic** regulation: vestibulohypothalamic connection? Proc Natl Acad Sci U S A. 2002 Nov 26;99(24):15723-8
6. **Mari M, Castiello U, Marks D, Marraffa C, Prior M.** The reach-to-grasp movement in children with autism spectrum disorder. Philos Trans R Soc Lond B Biol Sci. 2003 Feb 28;358(1430):393-403
7. **Teitelbaum P, Teitelbaum O, Nye J, Fryman J, Maurer RG.** Movement analysis in infancy may be useful for early diagnosis of autism. Proc Natl Acad Sci U S A. 1998 Nov 10;95(23):13982-7.
8. **Goddard S,** A Teacher's window into the Child's Mind, Fern Ridge Press 1996 :P1-4
9. **DELGADO SE, HALPERN R.** Breastfeeding of premature babies with less than 1500g: oral motor functioning and attachment. Pró-Fono R. Atual. Cient. [online]. 2005, vol. 17, no. 2 [cited 2008-08-28], pp. 141-152 doi: 10.1590/S0104-56872005000200003
10. **Yates BJ , Billig I, Cotter LA, Mori RL,** Card JP. Role of the vestibular system in regulating respiratory muscle activity during movement. Clin. Experi Pharmacology and Physiology, 2002; 29 (1-2): 112
11. **Miller AD, Bianchi AL, Bishop BP.** Overview of the neural control of respiratory muscles. In: Miller AD, Bianchi AL, Bishop BP (eds).Neural Control of the Respiratory Muscles. CRC Press, Boca Raton.1997; 1–4.
12. **]van Lunteren E, Dick TE.** Muscles of the upper airway and accessory respiratory muscles. In: Miller AD, Bianchi AL, Bishop BP (eds). Neural Control of the Respiratory Muscles. CRC Press, Boca Raton. 1997;47–58.
13. **Barsh LI.** Dentistry's Role in the Recognition and Treatment of Sleep-Breathing Disorders: The Need for Cooperation with the Medical Community JOURNAL OF THE CALIFORNIA DENTAL ASSOCIATION 1998, August
14. **Fogel RB, Trinder J, Malhotra A, et al.** Sleep-wake state Within-breath control of genioglossal muscle activation in humans: effect of sleep-wake state. J. Physiol. 2003;550:899-910;
15. **Harper RM, Sauerland EK.** The role of the tongue in sleep apnea In: Guilleminault C, Dement WC (eds). Sleep Apnea Syndromes. Wiley Liss, New York. 1978; 219–34.
16. **Lo YL, Jordan AS , Malhotra A et al.** Influence of wakefulness on pharyngeal airway muscle activity, Thorax 2007;62:799-805
17. **Popovic RM, White DP.** Upper airway muscle activity in normal women: influence of hormonal status. J Appl Physiol 1998; 84:1055–1062
18. **Cotter A, Arendt HE, S. P.** Cass SP et al Effects of postural changes and vestibular lesions on genioglossal muscle activity in conscious cats , J Appl Physiol 96: 923-930, 2004
19. **DHARANI Nataraj.** The role of vestibular system and the cerebellum in adapting to gravitoinertial, spatial orientation and postural challenges of REM sleep, Medical hypotheses ,2005; 65 (1): 83-89
20. **Stickgold R, Hobson JA.** REM sleep and sleep efficiency are reduced during space flight. Sleep. 1999;22(Suppl):S82.