II. REVIEW OF LITERATURE

The literature pertaining to the study on **"Accessibility and Adaptability of Limb Prosthesis –An Ergonomic Concern"** is reviewed under the following headings.

A. Prevalence of Disability and Amputations in India

B. Etiology and Premise for Amputation.

C. Repercussions of Amputation

D. Physiatric Management

E. Prosthetic Limb-an Ergonomic outlook

F. Status Quo-Accessibility of Limb Prosthesis

A. Prevalence of Disability and Amputations in India

The World Health Organization (WHO 2006) defined **Health** in a broader sense in its Constitution (1948) as "A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." Physical health is defined as an essential part of overall health of an individual, which include everything from physical fitness to overall wellbeing. Mental health refers to people's cognitive and emotional well-being. **Wellness** as quoted by National Wellness Institute is "a conscious, self-directed and evolving process of achieving full potential." There are eight dimensions of wellness: occupational, emotional, spiritual, environmental, financial, physical, social, and intellectual. Each dimension of wellness is interrelated with the other, and is equally vital in the pursuit of optimum wellness and health. **Physical Wellness** is the ability to maintain a healthy quality of life that allows a person to get through one's daily activities without undue fatigue or physical stress. Disability and impairment affect one's physical wellness.

Prevalence of Amputation in various countries

- USA =2055587
- Britain =421894
- India =7455494

International Database Statistics by country for amputation (2004)

From the average estimate of disabled (10% of all national populations) given by WHO (1981), the value was modified as four and seven per cent for developing and industrialized countries respectively in 1992, states, Metts (2000). Census 2001 had projected 21.9 million Indians to be suffering from some kind of disability that is equivalent to two per cent of the population (1,028,737,436). But the number of disabled, which was 2.1 crore in 2001, rose to 2.68 crore in 2011, with 1.5 crore males and 1.18 crore females. According to the census, 20.3 per cent of the disabled are movement disabled, a classification introduced in the 2011 census. Road and industrial accidents rendered many movement disabled in 2001-11 states Simmachandran (2013).

Amputation is derived from the Latin word, *amputare -"to cut away", from ambi- ("about", "around") and putare ("to prune"). Amputation* is defined as the removal, usually by surgery, of a limb, part, or organ. Its purpose is to remove dead or diseased tissue, to relieve pain, to obtain healing, and/or to rehabilitate the individual. It is a rescue procedure, the first step in rehabilitation (Kutz, 2009). ***Level of amputation*** is selected based on the potential for healing and future function. In the management of level of *Vascular amputation* (acute and chronic ischemia) the vascular status and potential need for amputation are evaluated, followed by assessment of the level of amputation. For *Traumatic amputations* or major tumors it is based on the nature of the injury and viability of the remnant tissue. The two primary goals of amputation surgery are the ablation of the diseased or traumatized tissues and reconstruction of the remnant or residual limb. In addition to the loss of motor function of the amputated joints, the amputee is also deprived of sensory information present in the intact limb. The most ***frequent level of amputation*** includes **transtibial (below knee)** amputation followed by **transfemoral (above knee) amputation**.

Amputations above/through the knee joint	Amputations below the knee joint
Knee Disarticulation - *performed through the middle of the knee joint*	**Transtibial** - *lower section of leg is amputated beneath the knee*
Transfemoral - *lower half of the leg and part of the thigh superior to the knee are amputated*	**Double Lower** - *both legs are amputated, commonly below the knee*
Hip Disarticulation - *procedure is performed through the hip joint, amputating the entire leg*	**Transmetatarsal** - *forefoot and toes are both amputated*
	Lower Digit - *one or more toes are amputated*

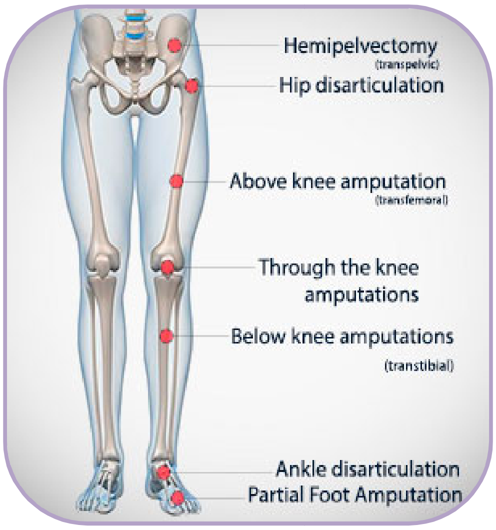


Figure: 1. Amputation levels of lower extremity

B. Etiology and Premise for Amputation

Etiology (alternatively aetiology or ætiology) is the study of causation, or origination. The word is derived from the Greek aitiologia, "giving a reason for" (aitia, "cause"; and -logia). The word is most commonly used in medical and philosophical theories, where it is used to refer to the study of why things occur, or even the reasons behind the way that things act. Etiologic factors involved in diseases include causative, predisposing and precipitating factors, which contribute to the onset of diseases. Disease causing factors determines the clinical features of the disease (https://en.wikipedia.org/wiki/Etiology). ***Medical, Surgical, and Psychiatric causes*** lead to amputation. Each can be devastating and difficult to manage.

Level of amputation	**Percentage**
Below Knee (Transtibial)	47%
Above Knee (Transfemoral)	31%
Below Elbow (Transradial)	8%
Above Elbow (Transhumeral)	4%
Through Ankle (Symes or Ankle)	3%
Hand amputations	2%
Through Hip and Hemipelvectomy	2%
Shoulder Disarticulation / Forequarter	1.5%
Through Knee (Knee Disarticulation)	1%
Through Elbow (Elbow Disarticulation)	0.5%
Source-WHO 2004	

Figure: 2 Level of amputation

1. Psychiatric conditions involving substance abuse, character disorders, or disorders of thought or mood that predispose to suicide attempts with limb injuries leading to amputation particularly challenging in primary care.

2. Medical causes of amputation include diabetes mellitus, osteomyelitis, peripheral embolization (from septic, fat, amniotic, or paradoxical emboli), PVD, thromboses (from disseminated intravascular coagulation), thrombocytosis (in hematologic malignancy), necrotizing soft tissue infections, and iatrogenic events (as from heparin-induced thrombocytopenia with thromboses). Malignancies, such as malignant sarcomas, may also require amputation.

3. Surgical causes can be divided into *accidental trauma* and *intentional or combat-related amputations*. *Accidental* trauma is associated with subway and train accidents, work-related construction and factory mishaps, falls, high-voltage electrical burns, and motor vehicle collisions. *Combat-related trauma* often caused due to the explosion of landmines and other sources of shrapnel (Braunwald et al., 2011).

1. Psychological Cause:

*a. Fixed dystonia***:** It is a disabling disorder mainly affecting young women who develop fixed abnormal limb postures and pain after apparently minor peripheral injury.

b. Body Integrity Image Disorder (BIID) or Amputee Identity Disorder (AID). It affects both sexes, with a male predominance. The affected individuals pretend to be an amputee (bending their legs, using crutches or bandages) usually provides transient relief. Over a period of time, most subjects seek an amputation, inflict injuries, or try to cut the limb themselves. The affected body part is always healthy and not painful (Mark, 2011)

Figure: 3. BIID affected Individual

2. Medical Causes:

a. Peripheral Vascular Disease (PVD): Almost all systems in body bear the brunt of diabetes and it is the long term complications chiefly vascular which pose a major challenge. It effects both large (macro vascular disease) and small vessels particularly capillaries (micro vascular disease). Progressive involvement of peripheral vessels especially of lower limbs is very common. Peripheral vessels are diminished and cyanosis is seen in dependent position (Khosla, 2008). Golwalla and Golwalla, (1999) classify them under:

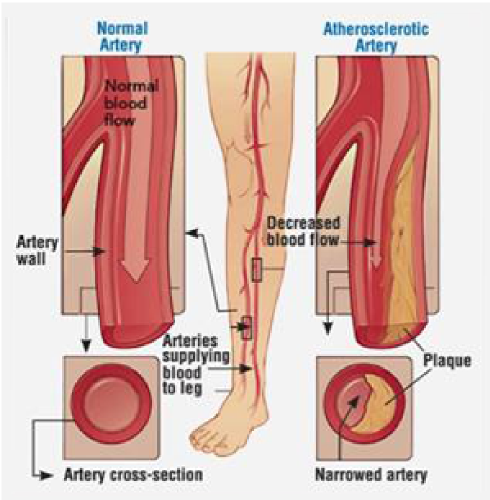


Figure 4 .Atherosclerotic Artery

- *Arterial Obstruction* like
  - (i) Degenerative diseases of Arteries: Atherosclerosis Obliterans
  - (ii) Inflammatory Disease comprises of Thromboangitis Obliterans, Infection like Sub acute bacterial endocarditis and Arteritis.
- *Vasomotor causes* - Raynaud's Disease.
- *Physical and Chemical agents* like
  - (i) Trauma: Contusion, fistulae and aneurysm.
  - (ii) Cold: Frost bite, trench foot and chilblain
  - (iii) Chemical: Phenol, ergot

Approximately half of amputations are performed on patients with diabetes, who have a 10 times higher risk of amputation. Age prediction ranges between 50 to 75 years. Uncontrollable soft-tissue or bone infection, persistent tissue loss (non reconstructable disease) or muscle ischemia (unrelenting rest pain) are the causes (Carmona et al., 2005). Rate of dysvascular amputation being nearly eight times greater than trauma related amputations (Amputee Coalition of America, 2010).

3. Surgical Causes:

a. Trauma**:** The second leading cause is indicated in younger patients and influenced by availability of medical care, degree of industrialization and transportation system (Moorell, 2013). More common in men because of vocational and avocational hazards

b. Accidents/ Injuries: Injuries can result due to

i). Military injuries: Affect the younger age groups either as direct shot or blast injury (Mannion, 2005).

ii). Occupational injuries: Poor ergonomics, manual handling of heavy loads, misuse or failure of equipment, exposure to general hazards, inadequate safety training to the employee, clothing and farming (www.cdc.gov/niosh/topics/ aginjury).

iii). Motor vehicle accidents: Trauma due to road traffic and railway accidents, and burns due to fire, electrocution, and chemical injuries (Pooja and Sangeeta, 2013).

iv). Falls**:** When running or from heights and construction accidents, the deadliest workplace injuries. Falls can be from scaffolding, ladders or roofs (Larsen et al., 2004). Burns: Thermal burns with extensive tissue necrosis or on those complicated by infection or electrical injury to an extremity (Yowler et al., 1998).

v). Frostbite: Actual freezing of tissue (direct tissue injury or ischemic injury) in the extremities, with or without central hypothermia.

vi). Infections: Infection of the bone (Thomas 2010).Necrotizing fasciitis caused by "Streptococcus pyogenes". Bacteria enter the body through small skin cuts and then travel to the bloodstream (http://www.nhs.uk/Conditions/Amputation/ Pages/ Why-it-is-used.aspx).Staphylococcus aureus or "MRSA"(methicillin-resistant staphylococcus aureus) which is either hospital acquired or community infection leads to amputation (www.amputee-coalition.org/inmotion/jan_feb_08/bacterial_ warfare. html).

vii). Tumors: Cancerous bone or soft tissue tumors and melanoma (http://en.wikipedia.org/wiki/Amputation).

Premise for Amputation: This section focuses on the physiologically, pathologically and psychologically complicating effects and causes of limb amputation**.** The topics presented, while covering a broad spectrum, exemplify the essence of an approach that includes physical, medical, pathophysiological and surgical constructs in addressing the precipitating and risk factors of the disease and limb-loss. In the progression of a disease, the cause of the disease can produce a result, and this result can also become another cause in the evolution process of disease leading to benign circle or a vicious circle.

1. Diabetes Mellitus: Has an effect on the pathology that may lead to lower limb amputation. The risk of amputation is higher where peripheral vascular disease and diabetes coexist. Peripheral neuropathy and ischaemia from PVD are two contributing factors to the development of foot ulcers. If once developed there is a high risk of wound progression leading to complications and amputation. Autonomic neuropathy causes reduction in sweat and oil gland function with the foot losing its natural ability to moisturize the overlying skin, increasing the susceptibility to tears or breaks with subsequent development of infection. Minor trauma also a can cause ulcers and eventual amputation. Poor healing of such wounds, due to compromised circulation, will eventually lead to amputation of the involved limb (http://www.physio-pedia.com/ Pathology_leadingfgv_to amputation).

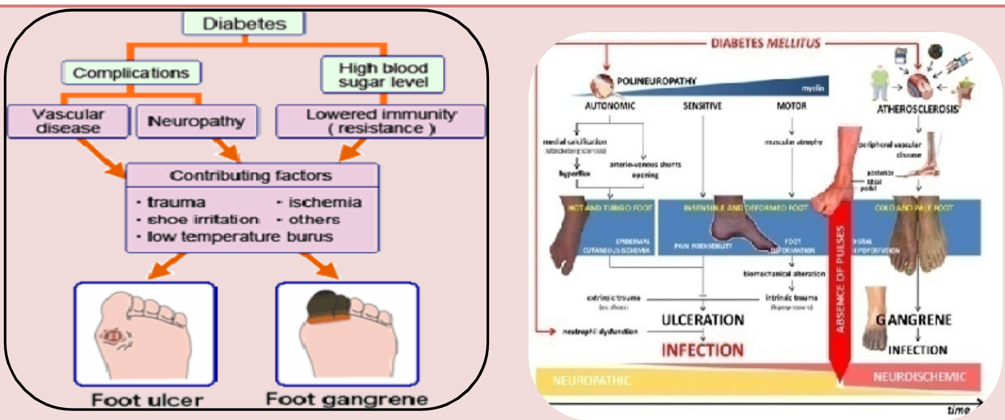


Figure: 5. Sequelae of complication of amputation

Source : Physiopedia

Diabetes-related Foot and Leg Problems leading to Amputee

- ***Infections and ulcers (sores).*** An ulcer is a sore in the skin that may go all the way to the bone. Because of poor circulation and neuropathy in the feet, cuts or blisters can easily turn into ulcers that become infected and won't heal. This is a common and serious complication of diabetes and can lead to a loss of foot, leg.
- ***Corns and calluses.*** When neuropathy is present, shoes cause pressure and produce corns or calluses .Corns and calluses must be properly treated or they can develop into ulcers.
- ***Dry, cracked skin.*** Poor circulation and neuropathy can make the skin dry. This may seem harmless, but dry skin can result in cracks that may become sores and can lead to infection.
- ***Nail disorders.*** Ingrown toenails (which curve into the skin on the sides of the nail) and fungal infections can go unnoticed because of loss of feeling. If they are not properly treated, they can lead to infection.
- ***Hammertoes and bunions.*** Nerve damage affecting muscles can cause muscle weakness and loss of tone in the feet, resulting in hammertoes and bunions. If left untreated, these deformities can cause ulcers.
- ***Charcot foot.*** This is a complex foot deformity. It develops as a result of loss of sensation and an undetected broken bone that leads to destruction of the soft tissue of the foot. Because of neuropathy, the pain of the fracture goes unnoticed and the patient continues to walk on the broken bone, making it worse. This disabling complication is so severe that surgery, and occasionally amputation, may become necessary.
- ***Poor blood flow.*** In diabetes, the blood vessels below the knee often become narrow and restrict blood flow. This prevents wounds from healing and may cause tissue death (http://www.foothealthfacts.org/footankleinfo/diabetic-amputations.htm).

2.* Vascular origin:* Eighty percent of all lower-limb amputations result from vascular disease. Vascular conditions account for most surgical amputations.

(a) *Dysvascularity*: In lower limb it is caused by Diabetes Mellitus (39%). Lower-limb amputations accounted for 97 per cent of all dysvascular limb loss, of which 25.8 per cent are above-knee level and 27.6 per cent, below-knee level amputation. It is the most common cause of lower limb amputation amongst all age groups due to infection episodes. It makes injured neuropathic limb infected (Viswanathan and Kumpatla, 2011).
(b) *Peripheral arterial disease* (PAD): occurs when there is significant narrowing of arteries, most often due to atherosclerosis, affecting several arterial beds (Burns, 2003 and Welten et al, 2009).

(c) *Raynaud's phenomenon* refers *to* transient cessation of blood flow to the digits of the hands or feet. It is frequently associated with pain and/or paresthesia due to sensory nerve ischemia. Amputation is needed for a finger or toe in which the blood supply has been completely blocked and thereby the tissue develops gangrene leading to partial amputation (John and Janice, 2005 and http://www.sclero.org/medical/ symptoms/ raynauds/treatment.html).

(d) *Cannabis arteritis* is a serious peripheral vascular disease affecting young adults consuming cannabis (Combemale et al, 2005).

(e) Acute limb ischaemia: Etiology is embolism, thrombosis, trauma and early-onset leg ischemia. Vascular conditions include haemorrhage, phlegmasia caerulea dolens, soft tissue injury like prolonged limb compression, crush injury or burns (Berridge, 2013).

(f) Cutaneous polyarteritis nodosa (PAN): Involvement of small and medium-sized arteries (Mitul, 2013).

***3.* Trauma**: Amputation is done at the point of injury (due to accident) i.e. a direct limb transection or may be due to severe open fractures or severe neurovascular injuries (Engstrom and Van de Ven, 1999).

Figure: 6 Crush Injuries

(a) *Crush injuries* is compression of extremities or other parts of the body that causes muscle swelling and/or neurological disturbances in the affected areas of the body. It tends to result in significant tissue damage and injury.

(b) *Crush syndrome or traumatic rhabdomyolysis* is localized crush injury with systemic manifestations..It is a reperfusion injury that appears after the release of the crushing pressure. The mechanism is believed to be the release into the bloodstream of muscle breakdown products—notably myoglobin, potassium and phosphorus—that are the products of rhabdomyolysis (the breakdown of skeletal muscle damaged by people who have been trapped under fallen or moving masonry (http://en.wikipedia.org/wiki/Crush_syndrome).

(c) *Guillotine Injuries* are Injuries involving sharp edges, resulting in less tissue disruption. (http://www.emsworld.com/article/10322826/tramautic-amputations).

(d) *Avulsion*: refers to an injury in which a body structure is forcibly detached from its normal point of insertion by either trauma or surgery. This type of injury often damages deeper tissues, causing significant bleeding. Amputations, sometimes controls bleeding because the tissue closes around the vessels at the injury site (http://www.sharecare.com/health/skin-injury/what-is-an-avulsion).

4. *Infections*: Infection is found to be the major cause of amputation in India .Almost 90 per cent of the patients has infection (Viswanathan and Kumpatla 2011)

(a) Osteomyelitis: Bone infection in and of itself may lead to many non-traumatic lower extremity amputations. It is one of the dominant complications of long standing diabetic foot ulcers among diabetics (Reiber et al., 2001). Diabetic immunopathy also increases the risk of soft tissue infection during this time (Kessler et al., 2005). Different types of germs (bacteria) can cause osteomyelitis leading to amputations (Thomas 2010). The long bones of the leg (femur, tibia and fibula) are the most commonly affected. (http://www.patient.co.uk/health/osteomyelitis-leaflet).

(b) Necrotizing fasciitis: Aggressive form of soft tissue infection due to Streptococcus pyogenes is a rare but very severe type of bacterial infection (Wong et al., 2003). Risk factors include diabetes mellitus, advanced age, obesity, liver disease, malignancy, alcoholism, or other immunosuppressive disorders (Espandar, 2011), leading to septic-toxic shock and progressive (multi-) organ failure (Käch, 1993).

(c) Meningococcal disease: Meningococcal septicemia is emerging as the most common clinical form of meningococcal disease (http://www.meningitis.org/ completed-projects/ study-of-children-with-14817).

5. Tumors: Means abnormal growth of tissue in some part of the body. Another group of sarcoma is bone sarcomas or bone cancer. There are three types of bone sarcoma: Osteosarcoma, Ewing's Sarcoma and Chondrosarcoma. Surgical removal of these tumors are mostly performed with limb salvage, but amputation may be required in some cases. Cancers that surround important nerves and arteries may need to be amputated (http://limblossinformationcentre.com/rehabilitation/amputation/causes-of-amputation).

(a) Osteosarcoma: Sarcomas in very young children are best managed by amputation (Robert, 2007).

6. Buerger's disease (or) Thromboangiitis Obliterans or presenile gangrene is a recurring progressive inflammation and thrombosis (clotting) of small and medium arteries and veins of the hands and feet. It is strongly associated with use of tobacco products, primarily from smoking, but also from smokeless tobacco. (http://www.nhs.uk/Conditions/Amputation/Pages/Why-it-isused.aspx).

Figure: 7 Buerger's disease

There is a recurrent acute and chronic inflammation and thrombosis of arteries and veins of the extremities. The main symptom is pain in the affected areas, at rest and while walking called claudication (Ferri and Fred, 2004). Ulcerations and gangrene in the extremities are common complications, often resulting in the need for amputation of the involved extremity (Porth and Carol (2007).

*7. **Limb Deficiency***: A child can be born with complete/ partial absence or formation of a portion of the limb. Two categories of limb loss exist: Congenital limb deficiency and Acquired amputations. (a) *Congenital Limb Deficiency*: Specific birth defects involving the arms or legs are called congenital limb deficiencies. It can involve either the upper or lower limb or multiple limb deficiencies. Environmental factors might include drug or alcohol abuse during pregnancy, infections, and exposure to certain medications or chemicals. Surgery is much more commonly recommended for lower-limb congenital deficiencies than for those involving the upper limbs (Douglas,2006). Lower-limb congenital deficiencies are evaluated to determine their ability to withstand the forces of weight bearing and walking and to assess the comparative lengths of each leg. Surgery may be necessary to modify the residual limb for prosthesis (http://www.oandplibrary.org/alp/chap33-01.asp).

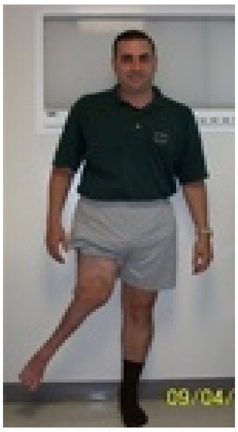


Figure: 8. Congenital Deficiency

(b) *Acquired amputations*: Result of cancer, trauma or severe infections. There are also unique abnormalities of blood vessels or nerves in children that can result in acquired amputations. One abnormality of the blood vessels is called severe hemangiomas.Another example is an abnormality of the nerves that causes congenital insensitivity to pain. In this condition, a child does not have feeling in his or her feet and an amputation may be required after repeated trauma, ulcers and infections. While these are congenital problems, the amputations are considered acquired because they happen later in life and result from complications of the disease (Douglas, 2006)

8. Smoking : Smoking is considered to be another or an added risk factor for lower limb amputation due to its effect on the circulation and potential for healing (Hampton and Collins 2004).

C. Repercussions of Amputation

Limb amputation is both a life-saving procedure and a life-changing event. Limb amputation affects all phases of an individual's life. Individual responses to limb loss are varied and complex, and are influenced by a range of personal, clinical, social, physical and environmental factors (Desmond, 2012). Amputees in addition to their physical disability suffer from myriads of psychological as well as psychosocial problems. There is little attention given on the psychological state of the individual unless he or she presents with overt behavioral abnormalities (Srivastava and Chaudhury, 2014). Thanni and Tade (2007) reaffirm that amputation results in a significant alteration to the body image, affects both the amputee and members of the family. Series of problems cited by Mugo (2010) enlist the following: living with a perceived stigma of deformed body image, feeling of emptiness and worthlessness, difficulty in social integration by feelings of being treated differently, lack of effective communication and expression in upper limb amputation, psychological problems such as anxiety and depression and economic set back due to loss of job or change of job

This chapter highlights these critical issues in amputation and summarizes the current knowledge and analysis in these domains which facilitates the researcher to design a study to address the issues.

Determinants of Psychosomatic Response of Amputees: Amputation is a triple threat involving the loss of function, sensation, and body image. The road to recovery can be relatively quick or prolonged depending upon age, psychological health before the loss, financial situation, circumstances of the loss (trauma, disease or congenital), society's values and support or lack of support from family and friends (http://www.oandplibrary .org/alp/chap28-01.asp).

1. **Psychological Responses**: The observed psychological response to amputation is determined by many variables.

(a) ***Age*:** The age at which one receives an amputation plays a role in the recovery process**.** ***I****nfants* born with a congenially missing limb adapt adequately as they learn to make compensatory use of their remaining faculties. Congenital limb anomalies children do not suffer traumatic alteration of their body image, as do those with an acquired disability reports MacBride, et al (1980). Amputee child typically assumes adjustment to amputation in a kind of an "all or none" phenomenon (Kahle, 2002). Kids are either completely adjusted or they're completely maladjusted. His research has proved that majority of children who experience amputation either congenital or traumatic copes well with their impairments and show remarkably good psychosocial functioning. ***C****hildren* adapt well to the loss of function and manipulate prostheses and other limbs with great agility, though they are particularly sensitive to their peer acceptance and rejection.

Younger the child, the more disturbing may be the presence of this phenomenon, since he/she cannot understand the disparity between the objective reality of the body and one's own feelings and sensations. Many other activities of daily living or psychomotor autonomy are felt to be severely limited. When less than four years of age, new abilities may be easy to acquire, yet adjusting to the new dimensions of one's body in an environment that does not appear to react as it used to may be a difficult and at times painful process. A traumatically acquired physical disability may also be perceived as a form of retaliation or punishment (http://www.acpoc.org/library/1968_04_007.asp).

P*readolescent or adolescent age group:* Amputation is a great threat to emerging sexual identity. They must make a lot of physical (body) and emotional (feelings) adjustments to major body changes like amputation. Physical adjustments often depend on where and how high the amputation is. Emotional adjustments can be varied and are not always in keeping with the extent of amputation. Teenagers with limb loss have the same "growing-up" problems as their peers, making their time harder because they do not want to be different from their friends. They may try to hide their limb loss. For instance, teenagers with lower-limb loss may not want to swim or do other activities that expose their legs (Smith, 2006).

The greatest challenges for the ***Y****oung Adult* amputee are in terms of identity, sexuality, and social acceptance. They do enjoy the advantages of an established identity, physical resilience, and social confidence. Hence, they tend to adapt well (Racy, 2015). Response to limb loss depends on its causes and the degree of disability and disfigurement. According to Desmond and MacLachlan (2002) for a young traumatic amputee, limb loss may represent the loss of life opportunities.

Among the ***E****lderly,* ill health, social isolation (especially after the death of a spouse), financial stringencies, and occupational limitations may all conspire to complicate adjustment to the limb loss. Proneness to risk like psychiatric disturbances as depression is also great (Arena et al., 1990). For those with peripheral vascular disorder, amputation may offer increased mobility, a decrease in pain, or both –a positive impact.

(b) ***Personality Style*****:** Individuals, who are *narcissistically invested* in their physical appearance and power, tend to react negatively to the loss of a limb, and see it as a major assault upon their dignity and self-worth. Conversely, *dependent* individuals may cherish the sick role and find in it welcome relief from pressure and responsibility. Those with a premorbid *history of depression* are more susceptible to dysphoria following amputation. The loss serves to crystallize notions of a basic defect, sometimes expressed in self-punishing behaviors. *Timid and self-conscious* individuals who are excessively concerned about their social standing are more likely to suffer psychologically from limb loss than are self-assured individuals. Although Kolb and Brodie (1984) report that *rigid* *personality style* may predispose to a greater incidence of postoperative complications, including phantom pain, Sherman et al (1987) indicate no such relationship to exist. Those tending toward a *pessimistic or paranoid outlook* are likely to find their worst expectations confirmed, and their rehabilitation may be colored by much bitterness and resentment. Unexpected reactions may arise from secondary gain. If disability results, in improved financial or social status, psychological adjustment may be made easier, especially if these gains are not directly challenged (Dise-Lewis, 1989)

(c) ***Job reintegration*****:** The success of resumption of work after amputation can be cataloged as: (i) *Demographically related factors:* These factors include age at the time of amputation, education level and gender. In patients between 18 and 60 years with an amputation of the lower limb, a major aim in rehabilitation is resumption of work.In subjects with a chronic disease, impairments and disabilities related to the specific disease also influence the success of job reintegration (Gollaher et al., 1998). Not only is training of physical mobility and independence in activities of daily living important after an amputation in younger patients, but return to work or school also have an important role. However, patients older than 40 years of age tend to show a decline in job participation. Problems with getting the right modifications of the workplace, and fewer promotion possibilities also influenced their return (Bruins, 2003). (ii) *Amputation-related factors*: These factors include co morbidity, amputation level, reason for amputation, skin problems of the stump, stump and phantom pain, use of prosthesis, wearing comfort of prosthesis, walking distance, mobility level, and type of rehabilitation (Schoppen, 2001). Physically, the body has to adjust to amputation setback, phantom limb pain, achieve functional abilities and person-specific functional expectations with the artificial limb to be able to perform activities of daily living. Psychologically, individuals have to come to terms with the changed life situation, cope with the amputation and its consequences, accept changes in body-image get used to the physical and mechanical features of the artificial limb; and socially perform social roles and maintain social contacts (Ustun et al., 2003). (iii) *Work -related factors:* These factors include education level and physical workload at the time of amputation (Schoppen, 2001). Several studies have stressed the importance of adjustments in the workplace to enable persons with amputations to continue working. Adjustments can be divided into four categories: changes in working time, getting aids, changes in workload, and other tasks or extra training. Other aspects that were found to be related to successful return to work of disabled people are: health perception, the extent of workplace adjustments possible, the type of work, and the expectations of the patients with respect to return to work. Many patients indicated that they had changed job and that the choice was influenced by the amputation as revealed by Schmidt et al (1995). Many studies have ascertained that through post- amputation there was a high return to work; people had switched over to less physically demanding jobs. People with a lower education level had more risk and failed to return to work than people with higher education. People with a higher education level ran more opportunities to control the scheduling of their work and to keep on working (Schoppen, 2001). Other reasons cited are the motivation of the amputee, his/her social situation and other job-related factors. A change in job obviously revealed their successful return to work (Schoppen 2001).

(d) ***Family variables***: Emotional responses to amputation are different for every individual and their family. It is common, however, to feel a sense of grief and loss. Being dependent and feeling a loss of control over their lives is one of the most frustrating changes that people experience after amputation (http://www.cdha.nshealth.ca/).

Disability places a set of extra demands or challenges on the ***family system***; most of these demands last for a long time. These challenges cut across disability type, age of the person with the disability, and type of family in which the person lives (Rolland, 1994). The initial response of most families to the sudden onset of disability is to pull together and rally around the person affected and provide support to each other (Steinglass et al., 1982). There is also a whole set of emotional issues that confronts family members, including grief over the loss of abilities; worry about the future and the costs; feelings of guilt, blame, or responsibility; and trying to find a cause and a meaning for this event. Families vary in how they deal with these emotional challenges. Some avoid them altogether and stay focused on gathering information and learning new behaviors. Other families are split, with some members having intense emotional reactions and others avoiding them. Even though there is expectation that family members should provide support to each other in times of crisis, it is often an unrealistic situation, when members are out of sync with each other. Family members may also respond with denial and feelings of anger and guilt (http://www.amputee-coalition.org/military-instep/psychologic al-concerns.pdf).The ultimate challenge to the family is to meet the disability-related needs and simultaneously to meet the needs of the family and its members of having a normal life (Gonzalez, Steinglass, and Reiss 1989).

Families with amputated children face distressing combination of feelings as fear, dismay, worry and sadness, and for most people also anger, confusion, grief and guilt. Acquired limb loss in childhood is a life changing event that will deeply affect the child, their siblings, and their parent. Parents of children with an acquired limb difference often report conflicting emotions: feelings of shock and disbelief; feelings of sadness and grief about the potential impact of a limb difference on their child's future; as well as feelings of relief and thankfulness that despite the circumstances their child will live (www.limbs4life.org.au).

The ***s****pouse* of an individual with a recent amputation also experiences a series of losses and adjustments. The spouse initially fears that the individual will die. This is followed by a fear of living with a person with a serious injury and a concern about accepting a person with a changed body. The spouse may experience the need for escape, loss of sexual arousal, revulsion, fear of ongoing economic dependency. Not only does their disability affect their activities, it also affects the partner's activities as well. They now always have to consider the needs of the amputees and fret on whether they can join the activity. In case of continuing such activities, that the amputee's spouse is no longer able to do, they wind up feeling guilty. Mental Stress that the amputee undergoes is horrendous, as there is constant preoccupation with pain. Constant worry necessitates watching the amputee torment in pain, when the partner's feeling is awful and their role shifts from being a partner to a care taker (http://www.posna.org/news/amputations.pdf). Their social interactions with other family members and friends may decrease due to their new role as a caregiver and their added responsibilities. Therefore, as primary caregivers of amputees they are prone to develop depression, and they too may need support from team members, peers, other family members and professionals (http://www.amputee-coalition.org/military-instep/psychologicalconcerns.pdf).

The ***a****mputee* may fear his inability to assume new roles within the family while they are consumed with grief. The change in function that results from amputation may require a total shift in responsibilities. The financial and emotional burdens can be overwhelming. For many couples this can cause serious strain on the relationship (http://www.posna.org/news/amputations.pdf).There is a considerable change in family activities of the amputees. With regard to household chores**,** it is often a reversal. The once equally-shared responsibilities become lopsided. The household jobs that were no longer done, is not only been done, but learning of various such household jobs that were never executed earlier was also learnt after amputation. Quality time spent together with the family changes. Family oriented amputees, in particular are able to adjust with their supportive partner who assumes a flexible approach, take over functions when needed, and at all times maintain the amputee's self-esteem. Persons with close family relationships, strong religious beliefs and caring friends seem to deal with their loss better than those without social support (Davidson et al., 2001). ***Elderly*** individuals may view themselves as a burden to their children and useless to society.

*(e)**Psychosocial Support***: The loss of a limb can have a considerable psychological impact. Many people who have had an amputation report feeling emotions such as pain and sadness (http://www.nhs.uk/Conditions/Amputation/Pages/Complications.aspx).The adult who experiences the loss of a limb often faces overwhelming feelings of losing control and of being dependent. Most people with amputations describe a feeling of complete change in reality due to lack of function, alteration of limb sensation, change in body image and lack of understanding of medical treatments (WHO Manual, 2004). It's common to experience negative thoughts and emotions after an amputation. This is especially true in people who have had an emergency amputation, as they do not have time to mentally prepare themselves for the effects of surgery (http://www.nhs.uk/Conditions/Amputation/Pages/Complications.aspx). Regardless of the cause of amputation, the amputee will probably go through basically the same psychological stages. The *grief process* involves ongoing emotions and reactions experienced by a person who is coping with a loss. It is considered a process because grief ranges in duration and intensity and happens over the course of time; with no specific end point (http://study.com/academy/lesson/normal-vs-abnormal-grief-responses.html). Amputee goes through the grieving process, where some people will do it in a short time, while others will take several months. With the loss of a limb, the two most common types of grief are *Anticipatory grief* and *Normal Uncomplicated grief*.

- *Anticipatory grief* occurs before a loss and is associated with a diagnosis of a life-threatening illness, and a forthcoming amputation.
- *Uncomplicated grief* is the process involving movement toward incorporated grief over time; with some periods of acute grief (Acute grief is response to a loss involving strong emotions, preoccupation with the incidence or avoidance of reminders of the incidence). Amputee still mourns the loss, and at times this can be intense and painful. But as time goes on, they will be able to participate in the activities of their life on a

regular basis again (http://study.com/academy/lesson/normal-vs-abnormal-grief-responses..html). *The Five Stages of the Grieving Process:*

1. *Denial:* Experienced by people who go through traumatic amputations, and normally those who have had surgical amputations will not experience it.

2. *Anger:* The person may get angry toward almost anyone or anything namely the situation responsible for the amputation, the medical personnel who could not save the limb or herself for being reckless**.** Often people will blame God, the doctor, or others for their loss (Saul Morris, 2015).

3. *Bargaining***:** In this stage, patients may attempt to postpone the reality of amputation, and most patients will try to bargain with their doctor or through a higher authority such as a religious figure.

4. *Depression:* In this stage, anger is replaced by depression. This is probably the most complicated stage of grief, but wade away. This is not clinical depression. It is normal. Common symptoms include sleeping either too much or too little, negative feelings about the environment and the future, feelings of hopelessness, and talking about death. It is treatable as it is not a sign of weakness. At the end of this stage the person feels anxious about the effect the amputation will have on daily living.

5. *Acceptance and Hope***:** Eventually, amputee will come to terms with the loss and start living again. Amputee starts to adapt to the physical loss of the limb and begins to make adjustments in their activities of daily living. Finally, starts to accept the loss of the limb and may no longer view it as a tragic situation (http://www.amputee-coalition.org/first_ step_2003/psychological-aspects-amputation.html).

People, who have had an amputation due to trauma, have an increased risk of developing post-traumatic stress disorder (PTSD). This is when a person experiences a number of unpleasant symptoms after a traumatic event, such as "reliving" the event and feeling constantly anxious (http://www.nhs.uk/Conditions/Amputation/Pages/Complicatio ns.aspx).

Complicated Grief is not common in amputee patients; their symptom includes severe isolation, violent behavior, suicidal ideation, workaholic behavior, severe or prolonged depression, nightmares, and avoiding reminders of amputation. Some people experience grief for a period of time, start their adjustment and then return to the earlier stages again. Others will appear to skip stages or may seem stuck in one stage of grief. Encouraging a person with an amputation to discuss his feelings openly helps him to relieve the anxiety and allows him to identify ways to approach his condition (http://www.posna.org/news/amputations.pdf). Individual with amputation is been devalued; that is they are not treated like other individuals; their disability is seen as signs of personal failure. Lower limb amputation is a permanent surgical procedure that has important functional, psychological, and social sequelae that can influence the Quality of Life of the person with amputation (Zidarov et al 2009). Perception of stigma as personal problem of the victims themselves can sometimes lead to disabled people being treated differently by non-disabled people because the latter may make assumption, on the basis of the disability, about all aspects of the individual's personality and functioning.

(f) ***Body Image*****:** Body image may be defined as the combination of an individual's psychosocial adjustment experiences, feelings and attitudes that relate to the form, function, appearances and desirability of one's own body which is influenced by individual and environmental factors (Horgan and McLachlan, 2004). An amputation induces several limitations in performing professional, leisure and social activities (Geertzen et al., 2009). It disturbs the integrity of the human body and lowers the quality of life (QoL) due to reduced mobility, pain and physical integrity. Patients are affected psychologically and socially. Psychological issues range from depression, anxiety and to suicide in severe cases (Atherton et al., 2006). Also, amputated victims see themselves as unfit for the society anymore after amputation and people in the society also see them as members of stigmatized group. The reason is that, body image not only provides a sense of ''self'', but also affects how a person thinks, acts and relate to others (Wald, 2004).

According to Breakey (1997) an alteration in an individual's body image sets up a series of emotional, perceptual and psychological reactions. He suggests that the loss of a limb by amputation could lead to a long-term disorder in the individual's body experience. Even when amputation does not interfere with one's ability to perform a job or to take part in social or recreational activities, it can have a great impact on self-esteem. Amputation results in disfigurement and may lead to a negative body image and potential loss of social acceptance (Jacobsen, 1998). As a result, people may focus their attention on the loss of normal physical appearance and attempt to conceal the disfigurement. Relationship between disability experience and stigma is not uni -dimensional, but are interwoven and inter dependent (Wald, 2004).

The loss of a body part also affects the perception of one's own body and its appearance. The perception of physical attractiveness is a complex construction of various psychological and physical factors. It is the degree to which a person's physical traits are considered aesthetically pleasing or beautiful (Adamson and Galli, 2003).The two main pillars of the perception of someone's appearance are body image and self-esteem (Ching et al., 2003). Body image is a person's individual perception of his/her own body and is a multidimensional dynamic process and affected by internal factors such as age, sex, physical condition as well as external factors including social or environmental factors (Holzer et al., 2014). A disturbance in this is the result of social values emphasizing vitality and physical appearance and fitness. Therefore amputation may be seen as a sign of failure. Amputees have to adapt physically, socially, and psychologically to alterations in structure, function, and body image ((Holzer et al., 2014). Losing a limb has been found to dramatically change a person’s sense of body image and consequently self-image, which is associated with a person’s satisfaction with life (Saradjian et al., 2008).

Less conventionally attractive people will likely receive less reinforcement from others, resulting in a decrease in self-esteem and a decrease in positive self-image. Therefore, amputation of a limb not only results in a loss of function and sensation but also requires a revision of body image (Breakey, 1997). Very *Young Children* may not be concerned about how they appear to others, but as they age, they tend to become more self-conscious. This is greatly heightened in their *Teen-age* years as adolescents become more aware of their changing bodies and those of the opposite sex. *Adults* can be just as self-conscious. When one doesn’t match up to social or personal standards, it may be hard to accept one or to be accepted by others (Winchell, 1996). Senra et al. (2012) explored the experiences of adult lower limb amputees focusing on the changes in self-identity related to the impairment. They conclude stating that self-identity changes after a lower limb amputation appear beyond the patient's body image and functioning, affecting the patient's awareness of the impairment, biographical self and any future projections.

2. Obesity and Amputation: Limb loss inherently brings additional burdens on many fronts (Kahle and Highsmith, 2008). Clinical observations prove that obesity occurs in many subjects after amputation (Kurdibaylo, 1996). Causes of obesity include depression, medications and an inactive lifestyle. Amputation can have a number of negative psychological effects, including major depression (http://healthyliving.azcentral.

com/amputees-need-work-out-10192.html). When some people eat more than usual, over a period of time, it will lead to weight gain, overweight or obesity (http://www.nhlbi.nih.gov/health/health-topics/topics/obe/causes).Overall activity level may decrease while the diet remains the same. Times of stress may even increase the daily calorie consumption. Unwanted weight gain can lead to heart disease, increased risk for cancer and other health problems (http://healthyliving.azcentral.com/amputees-need-work-out-10192.html).Those with the additional health problems end up having lot of medications (like corticosteroids, antidepressants and seizure medicines) which may cause gain in weight. These medicines can slow the rate at which the body burns calories, increases appetite, or cause the body to hold on to extra water (http://www.nhlbi.nih.gov/health/health-topics/topics/obe/causes).

It takes several months for most people to recover from injury, surgery, cancer, chemotherapy or radiation. Amputees are sedentary for a few weeks or months until their physical therapy begin, causing weight gain, and challenges in rehabilitation. Being overweight also reduces the stamina and makes it more difficult to walk on lower extremity prosthesis (http://www.hangerclinic.com/limb-loss/resources/living-with/Pages /Healthy-Lifestyle.aspx). Obesity affects amputees in unique ways:

a. Extra Stress on Joints: Orthopedic problems like osteoarthritis have been linked to weight gain (Kahle and Highsmith, 2008). An amputee puts increased stress on the joint(s) nearest to the amputation level. For a below knee amputee, the knee joint of the residual limb experiences increased stress, as well as the increased stress placed on the 'sound' limb, which most amputees favor. If a below knee amputee is obese, even more stress is placed on the residual limb knee joint (Robinson, 2015).

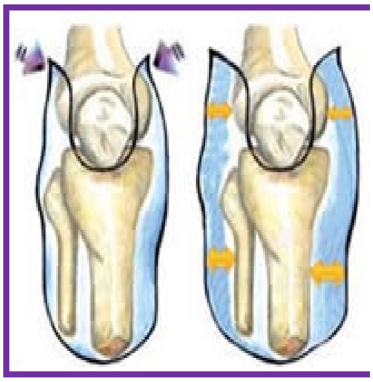


Figure: 9 Knee joint stress

b. Increased Cardiac Stress during Ambulation: People with amputation and obesity experience compounded cardiac demand and stress on the heart. Many obese amputees may be tempted to reduce activity, due to the increased stress. This reduction in activity will only perpetuate additional weight gain and keep the amputee in a cycle of inactivity (Robinson, 2015).

The absence of a limb and a portion of the muscular-skeletal system can c Zause physical strain on the rest of the body, not to mention the emotional strain of adapting to limb loss. Both the initial recovery and the long-term wellness will benefit from committing to a healthy lifestyle (http://www.hangerclinic.com/limb-loss/resources/living-with/Pages/Healthy-Lifestyle.aspx).

3) Mobility: The loss of a leg is a major disaster for all patients, limiting mobility and independence. For people with lower limb amputation, mobility can mean the difference between returning to home otherwise remain in a long term home care facility (Coletta, 2000). Mobility following amputation has a direct impact on quality of life. Preservation of the knee joint is associated with reduced energy expenditure. Additionally, ascending level of amputation is associated with increased metabolic demand. (Basu et al., 2008).

An individual who has a leg amputation is taught mobility using the intact limb only. By maintaining Center of Balance awareness patients maintain their mind's inherent ability to "perceive" where their amputated limb is in space or is called "proprioception". Walking (hopping) and standing with a walker automatically requires the patient to shift their Center of Balance over their sound foot, a lesson to the patients that it is the only limb they can rely on for safe ambulation (http://www.betterlimbs.com /_uls/resources/downloads/Transfemoral-Rehab_Book05.pdf).Hopping is not suitable for everyone. Hopping can be very demanding on the joints, muscles, lungs, and heart. It can also damage the remaining foot and cause problems. To be able to hop, the amputee should have a strong upper body, strong leg muscles on the remaining leg. This strength is needed to lift and lower the body weight and keep from slamming the remaining foot into the floor as amputee hop. Hopping is not a good proposal for people with diabetes, peripheral vascular disease, foot deformities, heart or lung conditions or arthritis in the remaining leg .Hopping may increase the risk for falling, which could cause injury to the stump or wound and delay healing (http://phc.eduhealth.ca/PHC_PDFs/FB/FB.132.L626 .PHC.pdf).

4) Employment Status: ***Unemployed amputees*** expressed unwillingness to get socially attuned as they found it difficult to get adjusted to their limitations. This restricts them functionally and socially. Amputees who have adjusted to amputation and prosthesis have more chances of being employed. Their economic independency due to employment status can make them more psychosocially adjusted and they tend to be more physically active. Commuting to work and performing the job would be requiring the amputees to perform some physical activity as compared to a non-working person, so the underlying motivation factor cannot be undermined, and the socio-economic status would be playing an important role (Schoppen, 2001) Unemployment is associated with a greater degree of psychological stress and may be a predictor of phantom pain. Individuals who earn their living from motor skills that are lost with the amputation are especially vulnerable to adverse reactions. Others who have a wide range of skills or whose main line of work is not particularly dependent on the function of the lost limb may experience less emotional difficulty. Of course, no amputee is completely insulated from the emotional consequences of discriminatory practices (Racy, 2015).

Employment, a factor deciding one's walking contributes most, in influencing adjustment to amputation. Employment is important to the well being of people, for instance in enlarging their social environment (Wevers, 1993).Chronically disabled persons have emphasized the importance of work for self-respect, giving meaning to life, and for a stable income (Bruin et al., 2003). Positive relation exists between long-term unemployment and health problems and reintegration and nature of jobs (Schoppen, 2001 and Andries, 1993)

Employers often judge chronically disabled people more negatively than their healthy colleagues (Hutchins, 1981). The relationship between insufficient modifications in the workplace and job dissatisfaction again emphasizes the importance of workplace adjustments in the process of job reintegration of amputees (Schoppen, 2002).

5) Job Characteristics: The main goal in the treatment of any injured person is to allow them to become independent and productive members of society. As such, the ability of an injured person to return to work is often used as a surrogate measure of functional outcome after injury (Burger and Marincek, 2007). Returning to active duty is good yard stick measure of recovery for combat-related amputees. This distinction not only signifies that an amputee has regained substantial function from a physical standpoint but also demonstrates an important recovery emotionally, too (Kruegera and Wenke 2014, Cross et al., 2012 and Akula et al., 2011). Tragic injury such as amputation presents inherent compromises to employment paradigm. Lost work time, a decreased possibility of promotion, and unemployment all pose threats to this important component of an individual's quality of life (Schoppen et al., 2002). In a society where the individual is valued for his production and wealth, he is seen as useless (Dornelas, 2010).

Bearing in mind the difficulty in returning to work or getting a job after rehabilitation, disabled people seek disability retirement to guarantee their income, with a high rate of retirees among young patients. Individual who survive after a road traffic accident evolve with immediate and/or late-onset sequelae. Accident sequelae include amputation of limbs, which can lead to several complications at the amputation stump, diminishing the individual's physical and social independence. The rate of return to work is low and disability retirement is common (Stevens, 2014 and Dornelas, 2010).

A timely and sustainable return to work is a crucial rehabilitation outcome for workers following injury, as prolonged work absences result in significant personal and societal costs (Lilley, 2013). Research findings point out that the length of workplace disability days were considerably higher among those with more proximal levels (transtibial, transfemoral, or hip disarticulation) of amputation (Herbert et al., 2006)

6) Pain: Pain is described as shooting, stabbing, boring, throbbing, pressing, burning and squeezing (Nikolajsen and Jensen 2001).Although amputation can be beneficial from a medical point of view, the loss of a limb may have a considerable impact on the patient's health-related quality of life. In the context of lower limb amputation *Wound*s and *Pain* is a significant problem. *Wounds* associated with amputation of the lower extremity continue to be a challenge. Patients who endure such wounds are often in poor health, with co-existing medical pathologies. Wound management in the lower extremity amputee has moved into a new era where complications such as infection, tissue necrosis and dehiscence are demanding more sophisticated therapies (Harker, 2006). Infection or wound dehiscence may prolong postoperative pain in some cases. It may also occur as a result of peripheral neuropathy (*e.g.* in those with diabetes) state Jackson and Simpson (2004). If unresolved, such pain is considered to negatively affect wound healing and to impact on quality of life. Pain persists and can even get worse with time. Pain and wound healing complications associated with the stump of an amputee are important because in some cases these determine a patient's ability to walk. The commonest stump-related complications were: wound infection and poor healing, poorly fashioned stumps and phantom pain.The healing rates for transtibial and transfemoral amputations vary considerably (Harker, 2006).

P*ain* secondary to limb amputation is common (Ephraim et al., 2005). Patients may experience immediate postoperative pain or may experience post-amputation pain including residual limb pain or phantom limb pain. In addition, patients with a lower limb amputation may have musculoskeletal pain (low back, hip, and knee pain) as a result of poor body mechanics or arthritis (Kurichi et al., 2015). Pain experienced after an amputation may scare and confuse patients (Donohue, 2001). They experience different types of pain like *Incisional Stump Pain and Phantom Pain* (Knetsche, 2001). *Stump pain* and phantom pain are common in the early post-amputation period but, in most patients, it subsides with healing. It is localised to the area immediately around the stump and the amputation scar (Ellis, 2002). Stump and phantom pain are interrelated phenomena. *Phantom pain* can be defined as painful sensations in the amputated limb and is a very real phenomenon (Nikolajsen and Jensen 2001). The etiology of post amputation pain is often multi factorial and its satisfactory resolution presents a significant challenge to the healthcare provider (Jahangiri (1994), Kooijman (2000) and Walsh (2005).

On the other hand, it is also possible that poor health related quality of life, for instance due to emotional problems, induces phantom pain. Although it is recognized that phantom pain may have a considerable impact on employment, and interfere with sleep and daily activities, information concerning the association between phantom pain and health related quality of life in amputees is very scarce (Schans et al., 2002).

7) Financial impedes: Mackenzie et al (2007) assert that treatment expenditure of patient with a unilateral limb-threatening lower-extremity injury treated in trauma centers included the costs related to (a) the initial hospitalization, (b) all rehospitalizations for acute care related to the limb injury, (c) inpatient rehabilitation, (d) outpatient doctor visits, (e) outpatient physical and occupational therapy, and (f) purchase and maintenance of prosthetic devices.

(i) Examining Expenses: When people become disabled, they not only are out of a job, but they also usually face higher expenses for medical expenditures, alterations to make their homes accessible and hiring people to do housework they used to do themselves.

(ii) *Identifying resources of Income:* All potential source of income should be identified after thorough scrutiny of sustained expenses - employer-paid disability policy, workers' compensation, NGO support etc states McNutt (2008)

People with disabilities may find it hard to cope with getting older. Amputation due to an illness (diabetes or vascular disease) affects older adults more often than younger ones. Retirement savings might drop due to unforeseen disbursement. People living on fixed incomes also struggle with unexpected costs such as amputation, special problems and rehabilitation. Many financial costs are due to lack of complete insurance coverage. Unfortunately, the quantity and quality of support services for elderly amputee aren't the same as that of younger amputee (http://www.amputee-coalition.org/inmotion/apr_08/needs_older_amputees.html).

8) Balance: Postural stability is essential to the performance of most daily activities and is necessary to lead an independent life (Sethy et al., 2009). Balance can be defined as the ability to regain the Centre of Mass (CoM) within the base of support to maintain body equilibrium. The Centre of Mass (CoM) reflects the centre of body location movement and changes accordingly to preserve balance (Vamos, 2010). In able-bodied individuals the ankle joint and leg musculature play an important role in maintaining balance by appropriately shifting the center of pressure (Sethy et al., 2009). Multi-factorial components contribute to postural balance. Horak (2006) suggested that six sub-components are required to retain postural balance, including biomechanical constraints, movement strategies, sensory strategies, orientation in space, control of dynamics, and cognitive processing. Static balance control serves as a balance indicator of dynamic control via postural sway. Postural sway can be defined as the deviation in the position of the centre of pressure (CoP) on the supporting surface (Ku et al., 2014).

Lower limb amputee patients experience greater imbalance compared with the normal population. This difference is associated with load distribution asymmetry, where more load is applied to the non-amputated leg as a result of etiology adaptation (Balasubramaniam and Wing, 2002). Gait and balance impairments may increase the risk of falls. Falling is an important clinical problem in amputee population (Sethy et al., 2009). An amputation can severely affect a patient's balance because their center of gravity will shift towards the remaining leg. This is a new experience not only to the body, but to mind as well. The mind actually needs to be re-educated in order to adjust to a new center of gravity (Fitzsimmons, 2011). Postural balance refers to the essential ability of maintaining daily functions (Sethy et al., 2009). With emphasis on persons with an acquired unilateral amputation above the ankle and below the hip joint; reorganization of standing balance has to be considered. Walking (hopping) and standing with a walker automatically requires the patient to shift their Center of Balance over their sound foot. This begins to teach the patient that this is the only limb they can rely on for safe ambulation (Maguire and Boldt, 2013).

9) Centre of Gravity: The *Center of Gravity* (CoG) *is* the *point* that defines the geometric center of a body. It is the point where all of the weight of the body is concentrated and is the point about which a body would balance without a tendency to rotate. Location of CoM remains fixed as long as the body does not change the shape. CoP and CoG are both related to balance in that they are dependent on the position of the body with respect to the supporting surface. CoG is subject to change based on posture (http://www.pt.ntu.edu.tw/hmchai/BM03/BMClinic/Stance.htm)

From a mechanical perspective, five factors determine one's levels of stability and mobility. (i) *Size of the base of support*. (ii) *Height of the center of gravity above the base of support:* (iii) *Location of the center of gravity projection within the base of support*: (iv) *Body mass or body weight*: (v) *Friction* (Whiting and Rugg, 2015).

Amputees possess by definition a functional asymmetry. There can be up to an 18.7 per cent loss in body weight for an entire leg (National Amputee Centre). This causes the center of gravity to shift up, back and toward the remaining limb. When the CoG is above the base of support and the pull of gravity is successfully resisted by the supporting members, equilibrium of forces or a state of balance is reached and no motion occurs (Jones, 2011).Individuals with a short residual limb have a larger sway area vs. individuals with a medium residual limb.Coordination assists with ease of movement and the refinement of motor skills. Both balance and coordination are required for weight shifting from one limb to another, thus improving the potential for an optimal gait (http://www.oandplibrary.org/alp/chap23-01.asp).

D. Physiatric Management:

Physiatry *or* ***rehabilitation medicine*** is a branch of medicine that aims to enhance and restore functional ability and quality of life to those with physical impairments or disabilities. Rehabilitation is important for enhancing the mobility of affected individuals and improving their health and vocational prospects (Pezzin et al., 2000). Limb amputation should not be viewed as a failure, but as a way of enabling the patient to function at a higher level. The importance of approaching amputation with a positive, constructive frame of mind cannot be overemphasized. For all concerned, it is a paramount goal to secure a prosthesis that returns what is missing in a functional manner (Legro et al., 1999). For amputees, rehabilitation starts preoperatively, they are psychologically prepared for the limb loss. After the surgical amputation postoperative rehabilitation takes place immediately. Early rehabilitation helps to avoid issues as deconditioning or joint contractures (Kurichi et al., 2010).

a) ***Stages of Rehabilitation***: Rehabilitation after limb amputation can be divided into nine discrete periods of evaluation and intervention. Each phase involves specific evaluation and treatment goals and objectives. The stages of amputation rehabilitation and the types of interventions to be used can be delineated according to the specific rehabilitation goals (Esquenazi and DiGiacomo, 2001). Esquenazi and Meier (1996) and Esquenazi (2004) suggest the nine phases of amputee rehabilitation as follows:

Phase	Hallmark
Pre-operative	Assess body condition, patient education, surgical level discussion, postoperative prosthetic plans
Amputation Surgery/Reconstruction	Length, myoplastic closure, soft tissue coverage, nerve, handling, rigid dressing
Acute post-surgical	Wound healing, pain control, proximal body motion, emotional support
Pre-prosthetic	Shaping, shrinking, increase muscle strength, restore patient locus of control
Prosthetic Prescription	Team consensus on prosthetic prescription and fabrication
Prosthetic Training	Increase prosthetic wearing and functional utilization
Community Integration	Resumption of roles in family and community activities. Emotional equilibrium and healthy coping strategies. Recreational activities
Vocational Rehabilitation	Assess and plan vocational activities for future. May need further education, training or job modification
Follow-up	Life-long prosthetic, functional, medical assessment and emotional support

Prosthetic Prescription: Prosthesis is an artificial extension that replaces a missing body part such as an upper or lower body extremity. It is part of the field of biomechatronics, the science of fusing mechanical devices with human muscle, skeleton, and nervous systems to assist or enhance motor control lost by trauma, disease, or defect (http://www.nist.gov/tip/wp/pswp/upload/239_limb_prosthetics_services_devices.pdf). It is multidisciplinary process referring to specification of the prosthetic socket design, commercial component (foot, knee units), suspension, and interface materials (insert, stump socks). Prosthetic selection is influenced by the age and general condition of the patient, his or her skin and vascular status, the presence or absence of disease, and any limitations imposed by such disease (Kutz, 2003). Brenner and Brenner (2008) propose that to provide the patient with the opportunity to try a variety of socket systems, with different load-bearing and suspension characteristics, it is necessary to custom fabricate each separate socket

b) *Prosthetic stages*: There are four generic post-surgical stages: postoperative, initial, preparatory and definitive or special-purpose prostheses. Although progression through all four levels may be desirable, only selected amputees will receive the post operative or initial prostheses, which are directly molded on the residual limb. Most amputees will have preparatory and definitive prostheses, and a much smaller number will receive special-purpose prostheses for showering or for swimming and other sports (Exhibit-2).

1.Postoperative Prosthesis:

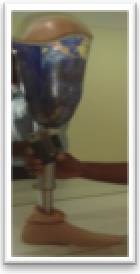
- Provided within 24 hours of amputation.
- Although technically feasible for virtually any amputation, postoperative fittings are currently most commonly prescribed for the younger, healthier individual undergoing amputation due to tumor, trauma, or infection.
- Its use in the elderly or dysvascular individual is controversial but can be successful when meticulous technique and close supervision are available.

2. *Initial Prosthesis*:

- Used in lieu of a postsurgical fitting and is provided as soon as the sutures are removed and until the suture line is stable and the skin can tolerate the stresses of more intimate fitting..
- Such devices are used during the acute phase of healing, generally from 1 to 4 weeks after amputation.
- Due to the usual rapid atrophy of the residual limb, this prosthesis is generally directly molded on the residual limb by using Plaster of Paris or fiberglass bandages

3. *Preparatory Prosthesis*:

- Used within a few days following suture or staple removal or during the first few months (3 to 6 months) of the patient rehabilitation depending on the speed of maturation of the residual limb and on other factors such as weight gain, weight loss, or health problems to ease the transition into a definitive device.
- They are also used in marginal cases to assess ambulatory or accelerate rehabilitation potential and help clarify details of the prosthetic prescription and limited gait training is started at that point.
- The modern preparatory limb usually incorporates definitive-quality endoskeletal component but lacks the protective and cosmetic outer finishing reducing the cost. Different types of knee mechanisms or other components can be assessed for functional improvement.
- It allows the therapist and prosthetist to work together to optimize alignment as the amputee gait pattern matures.



4. *Definitive Prosthesis*

- Not prescribed until the patients' residual limb has stabilized to ensure that the fit of the new prosthesis will last as long as possible.
- Based primarily upon the experience the patient had when using the preparatory prosthesis namely, lightweight design, special types of feet or suspension, or any special weight-bearing problems that may arise.

Two kinds of definitive prosthesis are recommended

- ***Traditional:*** The first type has rigid parts with the main function to support the bodyweight and aesthetically substitute a limb; they are usually made of wood or millwork resins.
- ***Modular:*** The second type has a supporting structure, which is tubular and modular, and it can have an external aesthetic soft cover. Due to their extensive adaptability to different types of amputees and to the possibility to substitute each single component of the prosthesis maintaining all the others their use is quickly increased.
- Definitive prosthesis is not a permanent prosthesis and its average life span is from 3 to 5 years. Since it is used during every waking hour it is mostly replaced due to changes in the amputee residual limb from atrophy, weight gain, or weight loss.

5. Special-Use Prostheses

- For activities like sports, swimming and skiing they are specifically designed.
- It is most economical if special-use devices are prescribed at the same time as a definitive replacement since both can be fabricated from the same positive model.
- Most require specialized alignment. For example, swimming prostheses are made waterproof and aligned so that the patient can walk without a shoe. In some cases the foot can be plantar-flexed and have a swim fin attached.
- Snow skiing prostheses require an increase in dorsiflexion at the ankle and may incorporate additional knee support or auxiliary suspension.
- Special-use prostheses can be valuable to the amputee who wishes to expand his activities and participate in a full range of sports and recreational pursuits (Gabbiadini, Stella 2011

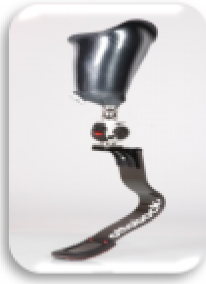


Exhibit 2 : *Prosthetic stages*

c) ***Elements of the Prosthesis*** include *Structural interface, Soft Tissue Interface, Joint Systems, Skeletal Components, Suspension Systems and Control Systems*.

i). *Structural interface* is the part of the artificial aspects of the prosthesis that the body connects to in order to interact with the environment. The **p**rosthetic **s**ocket joins the residual limb to the prosthesis and fulfils an important function of it ensuring optimum adhesion and the proper fit of the prosthesis. The prosthetic socket is custom-made for each patient according to the shape and condition of the residual limb and the respective mobility grade.

ii). *Soft Tissue Interface*: Prosthetic socks and liners are examples of soft tissue interfaces. Worn next to the skin these types of interfaces provide a barrier between the body and the structural interface to allow for movement and the changing nature of the human body.

The ability to add or take away plys of socks allows the patient to maintain a safe functional interface with the socket and allows for maximum comfort and the health of the skin. The prosthetic socket consists of a liner, a matching closure system and a load-bearing outer wall (the actual socket), which forms the connection to other components (knee joint, prosthetic foot). The liner acts as a sort of “second skin” between the movable soft tissue of the residual limb (muscles, tissue, skin) and the hard shell of the socket. This minimises movement and friction between the skin and prosthetic socket. The “second skin” is a thin protective membrane made of a flexible material that is rolled over the residual limb and protects the sensitive skin on the residual limb by reducing friction and pressure points of the residual limb in the socket. Selecting the right liner is essential in order to ensure that the prosthesis fits well and is comfortable to wear. But a liner can only ensure optimum safety and comfort in combination with the right closure system that keeps the socket in place on the residual limb. The prosthetic socket assumes the load-bearing function within the entire socket system. It constitutes the connection to the other components.

iii). *Socks:* Traditionally, prosthetic socks provide cushioning and a means to adjust the volume of the socket. They are available in several materials including wool, cotton and synthetics. Sock thickness is measured by the “ply” rating, most commonly from 1-ply to 6-ply. By varying the ply number and/or the number of socks worn, amputees can adjust for changes in the size of their residual limb. While protecting the skin and from forces of pressure they should also absorb perspiration with a wick-like action and allow for ventilation. Materials for the socks include wool, cotton, synthetic fibers, nylon sheaths and gel socks (http://www.amputee-coalition.org/military-instep/prosthetic-socks-liners.pdf).

iv). *Joint Systems*: Replacement of joints depends on the level of amputation,. Feet, ankles, knees and hips are the joint systems for lower limb prostheses. The function of a mechanical knee joint is vital to the overall performance of transfemoral prosthesis the component that bends (flexes) and straightens (extends) to allow for standing, normal walking, sitting, and kneeling. Endoskeletal knees are made of a variety of materials, such as stainless steel, titanium, and various composites of graphite, acrylic, or epoxy. There are many classes or types of knees, ranging from the very simple to extremely complicated designs (Schuch, 1998).

v). *Skeletal Components* is the part of the prosthesis that connect the joint systems and the structural interface (socket) are called skeletal components. The shank corresponds to the anatomical lower leg, and is used to connect the socket to the ankle-foot assembly. In an endoskeletal shank, a central pylon, which is a narrow vertical support, rests inside a foam cosmetic cover. Endoskeletal systems allow for adjustment and realignment of prosthetic components.

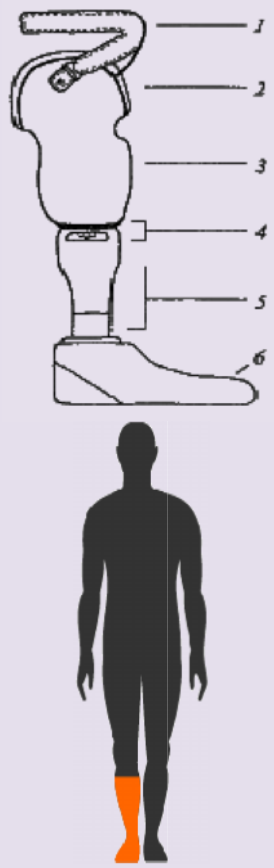
vi). *Suspension Systems* are used to hold the prosthesis onto the body**.** The type of suspension is determined individually for each patient based on their needs and activity levels, as they keep the prosthesis firmly in place during use and allow comfortable sitting. Several types of suspension exist, both for the transtibial and transfemoral amputation. Common transtibial suspensions include sleeve, supracondylar, cuff, belt and strap, thigh-lacer, and suction styles. Sleeves are made of neoprene, urethane, or latex and are used over the shank, socket and thigh. Supracondylar and cuff suspensions are used to capture the femoral condyles and hold the prosthesis on the residual limb. The belt and strap method uses a waist belt with an anterior elastic strap to suspend the prosthesis, while the thigh- lacer method uses a snug-fitting corset around the thigh. The suction method consists of a silicone sleeve with a short pin at the end. The sleeve fits over the residual limb and the pin locks into the socket. With transfemoral prosthesis, suction and several types of belt suspension also are available.

vii). *Foot-ankle assembly* is designed to provide a base of support during standing and walking, in addition to providing shock absorption and push-off during walking on even and uneven terrain. Four general categories of foot-ankle assemblies are non-articulated, articulated, elastic keel, and dynamic-response. One of the most widely prescribed feet is the solid-ankle-cushion-heel (SACH) foot, due to its simplicity, low cost, and durability. It may be inappropriate, however, for active community

viii). Ambulatory and sports participants (May, 2002).

ix). *Control Systems*: Prosthesis is primarily mechanically controlled by body power. However, there are innovations in myo-electric, microprocessor and bionics that enable some prostheses to have externally power controlled assistance (http://prostheticclinic.com/prosthetic-limb-design/)

d) Lower-Extremity Prosthesis provides replacements at varying levels of amputation. These include hip disarticulation, transfemoral prosthesis, knee disarticulation, transtibial prosthesis, Syme's amputation, foot, partial foot, and toe. The two main subcategories of lower extremity prosthetic devices are provided based on the level of amputation. ***Transtibial*** amputation is transecting the tibia bone or a congenital anomaly resulting in a tibial deficiency and ***transfemoral amputation is*** amputation transecting the femur bone or a congenital anomaly resulting in a femoral deficiency (http://en.wikipedia.Org/wiki/Prosthesis).



1. The strap (alternatively a sleeve) - to hold the prosthesis on.
2. The liner – a soft insert for shock absorbing.
3. The socket – custom-made to fit the amputee and distribute weight.
4. The alignment unit - used to move the foot for optimal walking.
5. The pylon - distributes weight from the socket to the foot.
6. The foot - made to imitate normal foot function.

Figure : 10 .Parts of the Transtibial Prosthesis

Transtibial Prosthesis*:* There are many types of below knee prostheses.

(1) ***Socket*** design is determined. The socket type that an amputee is fit with depends on the shape of the residual limb, activity level, prognosis, and individual preference. Biomechanics of socket-residual limb interface (Figure 10) especially the pressure and force distribution, have effect on patient satisfaction and function (Pirouzi et al., 2014). Socket shape can influence pressure distribution. The ideal socket can be a compromise between tightness and shape, with a tight socket improving coupling between the stump and prosthesis, but also increasing pressure. Conversely a loose socket may relieve pressure, but increases risk of slippage. Most prostheses for amputations between knee and ankle consist of three major parts: a socket, a shank, or shin, and a foot (http://www.aoptinc.com/PDF/Below%20Knee %20Prostheses.pdf).The three main types of socket designs are: PTB or Patella Tendon Bearing, Silicone Suction Suspension (3S) and Vacuum Assisted Socket System (VASS). Exhibit -3 shows the different types of socket designs (http://www.austpar.com/ portals/prosthetics/transtibial_sockets.php).

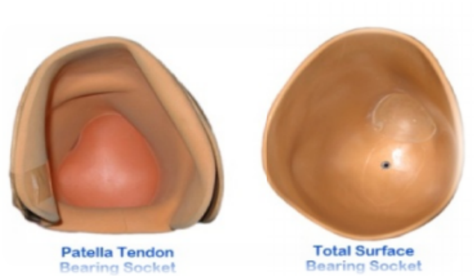


Figure: 11. PTB and Total Surface Socket

(2) *Suspension Sleeve*: A sleeve is one that is attached to the prosthesis and rolls onto the amputee's thigh, creating a seal and holding the prosthesis on the limb. The sleeve may be made of neoprene, gel, or various fabrics. Suprapatellar Cuff and Waist Belt: Suspends the prosthesis from around the waist. It is a very secure form of suspension and also allows some adjustability by the amputee. Some patients are able to achieve suspension with only the use of the cuff.

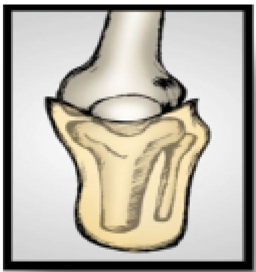
(3) Joint and Corset: Prosthesis is held on by a corset that is laced around the amputee's thigh and attached to the prosthesis using metal joints. A fork strap and waist belt may also be needed for additional suspension. A joint and corset is only used when another option is not possible. It is used when the amputee has a very short residual limb, or has weaker muscles around the knee and can tolerate only light weight (http://www.aoptinc.com/PDF/Below%20knee%20Prostheses.pdf).

Different types of socket designs

Socket PTB (Patellar Tendon Bearing): The weight bearing takes place below the patella, at the patellar tendon. The suspension is generated by a belt that is tightened around the distal part of the thigh. The tension of that belt limits the blood and lymphatic circulation; moreover, after long term use results in muscle atrophy and other related problems.

Socket PTB SC (Patellar Tendon Bearing Supracondylar): The weight bearing takes place below the patella, at the patellar tendon. The suspension is generated at the medial and lateral areas of the femoral condyles. Compared to the PTB socket with belt suspension, this design does not produce problems of blood circulation or atrophy. For the moment, this type is used worldwide as most basic design for prosthetic fitting of medium and long stumps

Socket PTB SC SP (Patellar Tendon Bearing Supracondylar Suprapatellar): The weight bearing takes place below the patella, at the patellar tendon. The suspension is generated at the medial and lateral areas of the femoral condyles and at the suprapatelar area. This type is indicated for short stumps, as well as in cases of antero-posterior instability in the knee.



Total Surface Bearing Sockets

Socket SSS (Silicon Suction Socket): The weight bearing takes place all over the stump surface. The suspension is generated by means of tight adhesion/friction between stump and silicon liner that has a pin at its distal part. This pin is installed in a blocking mechanism inside the prosthetic components, hence insuring the suspension. Indicated for all types of stumps.

Vacuum Assisted Socket System (VASS)

This system is a relatively new socket and suspension method. The goals of the system are to control volume fluctuation of the residual limb, reduce forces to the limb, and to improve both suspension and proprioception without restricting vascular flow. With this system, a polyurethane liner is directly against the skin and a suspension sleeve is used to create a seal between the prosthesis and the residual limb. Harmony vacuum pump is below the socket that evacuates the air from the system with each step (http://www.healthcareaccessorie com/vacuum.htm)

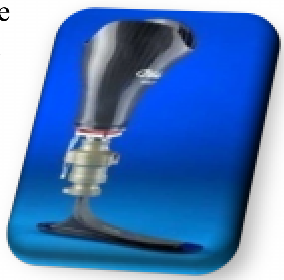
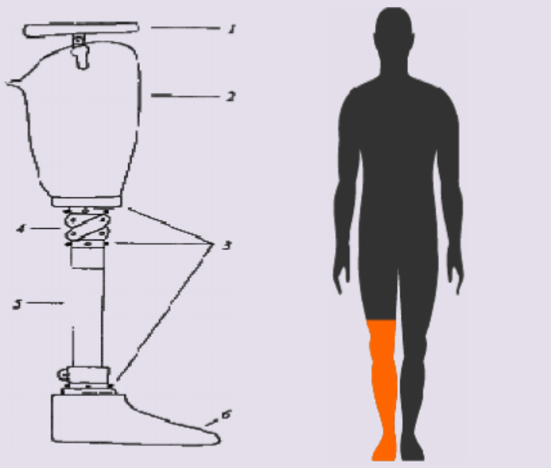


Exhibit 3 : Type of socket design

Trans-Femoral Prosthesis: Above knee prostheses (Figure-12) are available in several designs, usually depending on the patient's age, activity level, residual limb size and shape, as well as their diagnosis and prognosis. Amputees are unable to bear weight on the bottom of the femur, thus body weight is supported by loading the ischial tuberosity and the soft tissues of the limb [primarily the gluteal muscles] with the soft tissue of the residual limb bearing only a minimal amount of weight. The above knee amputee will always feel some pressure on the ischial tuberosity because they are essentially sitting on the socket (http://www.brownfieldstech.com/above_knee.asp).



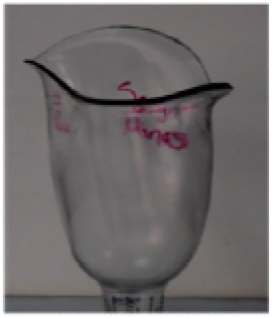
1. The pelvic band/suspension strap (alternatively a suction socket) - to hold the prosthesis on
2. The socket – custom-made to fit the amputee and distribute weight
3. The alignment units - used by the clinical prosthetist to alter the position of the knee and foot for optimal walking
4. The knee - bends for sitting and swinging, but extends for standing and walking. There are three basic knee types - locked, safety and free
5. The pylon - distributes weight from the socket to the foot
6. The foot - made to imitate normal foot action

Figure: 12. Parts of Trans femoral Prosthesis

(1). Socket design is termed an ischial containment socket. In ischial containment socket the amputee is essentially 'sitting' while walking because they are bearing the majority of their body weight through their ischial tuberosity. The goals of the above knee prosthesis are to provide a comfortable prosthesis, that enables the amputee to regain stability during walking and any other balance related activities, and a prosthesis that is cosmetically appealing. Comfort is attained by having a socket that has a hard external frame and soft inner shell. The hard external frame is a lamination comprised of fiber glass, carbon fiber, and epoxy acrylic resin. The soft inner shell is made a plastic composite. This external framing allows for musculature to suit different phases of walking without causing discomfort within the prosthesis (http://www.o-pspecialists.com/services/prostheticservices/aboveknee.html). Exhibit-4 shows the two types of transfemoral socket prescribed.

Quadrilateral Socket

The weight bearing takes place at the ischial tuberosity by means of the ischial support at the posterior shelf of the socket. The suspension is provided by negative pressure (suction) that is generated by adequate fitting of the socket over the stump. In some cases, the suction suspension can be complemented by the use of belts (Silesian, Neopren, etc.). This type of socket is in most use for all types of stumps.



Transversal view **Medial view** **Posterior view**

Ischial Containment Socket

The weight bearing takes place all over the surface of the stump without localizing one specific point; hence, generating more comfort and better control over the prosthesis and security for the user. The ischial tuberosity does not suffer from direct, complete and permanent weight bearing. The principal peculiarity of this design, a part of the exact volume determination, is the medial wall/border of the socket that contains the ischial ramus. Suction suspension refers to the negative pressure or suction that is created between the residual limb and the smaller prosthetic socket. Suction suspension helps the prosthesis feel lighter to the wearer because it is a positive suspension and little movement occurs between the residual and the socket. Persons using suction suspension must have stable volumes of their residual limb. This type of socket is in worldwide promotion, replacing the quadrilateral one**.**

Transversal view **Medial view** **Posterior view**

Exhibit 4 : Types of transfemoral Socket

(2).*Knee System:* Prosthetic knee joint is one of the most critical components of the prosthesis. Replacing the amazingly complex human knee has been an ongoing challenge since the beginning of modern prosthetics. A prosthetic knee has to mimic the function of the normal knee while providing stability and safety at a reasonable weight and cost (http.//www.amputee-coalition.org/resources/the-prosthetic-knee/).The majority of the prosthetic knees used worldwide can be divided into two groups depending on the number of axes.

Uni axial Knees: During flexion/extension these articulations execute a simple rotation around the knee axis. They are of simple design and their easy alignment responds to the rules of mechanics. Both versions (exoskeletal and endoskeletal knees) have manual or automatic blocking of the flexion to be used in users with poor muscle power. The knees without blocking can be used for regular prosthetic fitting of amputees with adequate muscle control and/or in situations of limited economic resources.

Poly-axial Knees: Based on principle of two or more axes of articulation. Knees of the most frequent use are of 4 axes (or 4 bars). Without giving importance to the number of axes, the knees of poly-axial design have one thing in common - the Instant Centre of Rotation (ICR) is situated much higher and posterior than the mechanical axes when the knee is in extension (http://www.physio-pedia.com/Prosthetics).

The other type of knees include: *The non-microprocessor knee* that uses a mechanical hinge. The speed and ease of the hinge's swing is controlled by one of the following mechanisms: free swing, manual lock, constant friction, weight-activated friction, geometrically locking and hydraulics. The hinge swings, and then locks manually when pressure is placed on the leg during stance phase. Mechanical-knee users must exert muscular and mechanical control to alter speed and step length and provide stability in the weight-bearing phase of gait. The prosthetist or the amputee can manually adjust some mechanical knee joints to set the controls in the swing and stance phases based on the patient's needs. These adjustments can only be made when the person is in a static (still) position.

The microprocessor controls the speed and ease with which the knee swings throughout the swing phase. It also controls the degree of stability the knee joint maintains during stance phase. Microprocessor-controlled prosthetic knees are equipped with sensors that continuously detect the position of the knee throughout the stance and swing phases of gait. These sensors provide input to the prosthetic knee so that the knee “knows” which gait phase it’s in. This allows it to adapt to different walking speeds, terrain and environmental conditions as the amputee walks. Microprocessor knees use a variety of systems within the knee mechanism to provide resistance, including pneumatics, hydraulics and magnetic systems. Each type of microprocessor knee uses software that controls and modifies the function of the knee (http://www.amputee-coalition.org/resources/the-prosthetic-knee/) Exhibit 5 shows the different types of knee used for the amputees in their prosthetic limbs.

(3).*Suspension*: The most common types of suspensions for the above knee prosthesis are: *Silesian band* made of cloth or leather, this belt wraps around the waist below the pelvic bone and above the hip. The belt attaches to the lateral wall of the prosthesis and buckles into the front wall of the prosthesis.

Pelvic band with external hip joint: Used when the person with an amputation has a short limb or weak hip musculature with decreased ability to control hip movement, particularly hip abduction or movement of the limb out to the side. *Suction suspension* does not need a belt but requires the socket to be in direct close contact with the skin. Prosthetic socks are not worn with this type of socket. There is an air valve at the bottom of the socket to allow the person with amputation to push the air out of the socket. This creates negative pressure or suction inside the socket (Suction suspension).This suspension is frequently used in younger more active persons with amputations. Putting on this type of socket requires strength, balance and coordination. The advantages of this system is the increased freedom of motion allowed while promoting the use of the remaining thigh musculature and improving comfort if correctly fitted. *Shank:* This is the part of the limb that connects the knee and the foot. It is made of durable materials such as rust proof metal, wood, hard foam or plastic (http://www.posna.org/news/amputations.pdf).

(4) Prosthetic Feet can be made from wood, rubber, urethane, titanium, graphite and carbon fibre. They can be lightweight, energy-storing or dynamic and some can allow adjustability of heel height. All prosthetic feet should provide passive plantar flexion in early stance, neutral position in mid stance and toe hyperextension in late stance. *Non-Articulated Feet:* Generally known as SACH (Solid Ankle Cushion Heel) feet and consist of rigid feet without ankle articulation, where the heel absorbs the shock and the forefoot simulates the dorsal flexion of the foot. In spite of having a very simple design, SACH feet respond to functional necessities in all the phases of the gait.

Compact SAKL

- A compact, lightweight & low cost knee system.
- Locks automatically when straightened.
- Self adjusting locking mechanism.
- Low maintenance.
- Multiflex ankle for natural walking action.
- Structurally tested for up to 100 kgs user weight.

Modular Monocentric Safety Knee Joint

- Monocentric Safety Knee Joint with extension assist is recommended for patients requiring stability but are able to walk without a locked knee joint.
- The weight activated locking mechanism provides stability in the stance phase and a spring unit assists in the extension.
- It is very light weight, thus easy to handle by the patient.
- Structurally tested for up to 100 kgs user weight.

Mechanical 4 bar linkage Knee Joint

- Polycentric knee joint makes it geometrically stable.
- Viscous elastic swing.
- Maximum load capacity of 125 kgs.
- The extension stop allows adjustment of the instantaneous center of rotation.
- For low walking demands and high safety needs.

ESK+ PSPC

- A unique combination of ESK+ and Pneumatic Swing Phase Control Technology.
- Adapts better than standard Pneumatic Phase Control Technology to small gait variations.
- Independent adjustment of flexion and extension rates.

ESK + MKL

- Weight activated stance control
- Pneumatic swing control
- Manual user operated lock
- 115° knee flexion
- Enhanced brake drum surface with dust covers
- Simple access for stability adjustment
- Universal thigh release
- Proximal full alignment
- Pyramid, full shin or tube clamp distal options

EUK-Hydraulic Cylinder

- Suitable for active wearers when fitted with a swing control.
- Swing control options include hydraulic and pneumatic.
- Stance flex knee absorbs the impact of heel strike.
- 115° knee flexion.

KX 06

- A unique polycentric knee with hydraulic swing and stance control which delivers truly active gait with enhanced transition from stance to swing.
- The geometric and hydraulic combination draws on the best functionality of each to enhance the overall gait smoothness on all terrain from flat to steep slopes
- 145kgs weight limit
- 160° of knee flexion

Exhibit-5. Types of Modular Knee

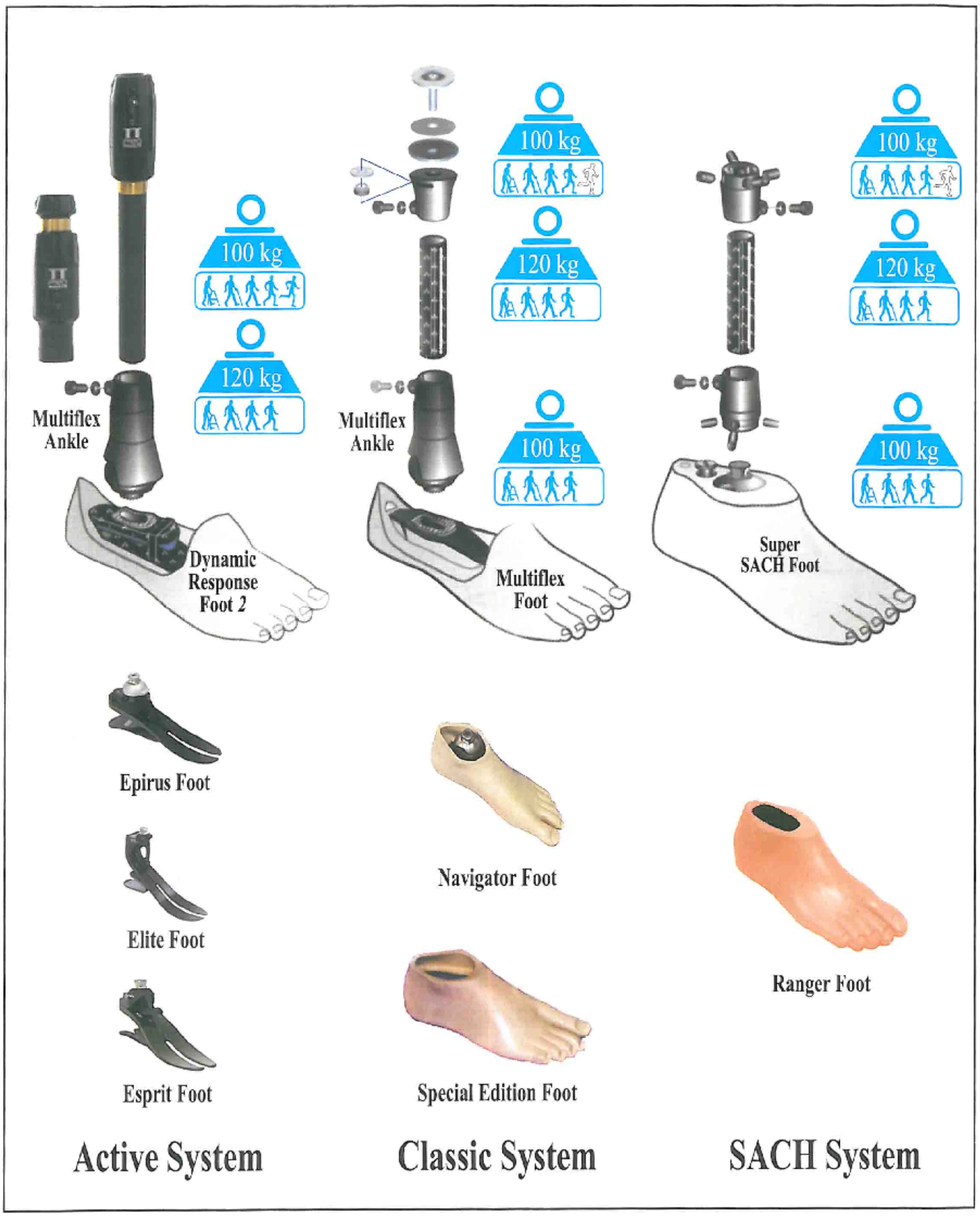


Exhibit – 6. Types of Modular Feet

Feet with Energy Return: The basic element of these feet is the design of the keel that simulates a spring molded carbon fiber plate. This design has better energy response during the toe-off phase (imitating the natural impulse of the foot) by means of the shape and the material of the keel (http://www.physio-pedia.com/Prosthetics#cite_ref-17). Exhibit-6 Types of Feet used in Modular Prosthesis.

E. Prosthetic Limb-an Ergonomic outlook

The word "Ergonomics" comes from the Greek "Ergon" meaning work and "Nomos" which means law. Therefore, etymologically, this is the science of work.

In its triennial report, the International Ergonomics Association (IEA, 2000) defined ergonomics as the scientific discipline that deals with understanding the interaction between humans and other elements of a socio-technical system. In this definition, **Ergonomics is the profession** that applies theory, principles, data and design methods to optimize human well-being and the *overall performance of a system*. The prosthetic leg (PL) is a typical human-machine system in which the dynamic interaction between the human body and prosthetic leg (machine) determines a high requirement of ergonomics design for prosthetic leg and consequently needs to consider an indicator of usability indicating the performance of gait biomechanics (Hong-Liu 2011). Accordingly, one can recognize today four main domains of expertise crucial for investigating interaction between humans and socio-technical systems that include *Physical, Cognitive, Neuro and Social or Organizational Ergonomics* (José, 2011). The physical interaction between the human users and the elements of the system should be carefully taken into account to fulfill the requirements for an ergonomic design of a wearable prosthetic system for motion assistance and rehabilitation. In particular, the ergonomic design of wearable prosthetic devices that are, by definition, parallel and physically coupled with a human limb should be compliant with the human model in terms of *Anatomical, Anthropometric and Biomechanical Characteristics* (Chiri et al., 2012). A truly ergonomic wearable device smoothly interacts with the user’s limb and provides a safe and comfortable human robot interface. Two main key requirements for structural ergonomics are the correct kinematic axes alignment with the human limb and a comfortable and adaptable physical-human-robot interface-socket (Chiri et al, 2012).

1. Physical Ergonomics*:* deals with the anatomical, anthropometric, physiological and biomechanical parameters in static and dynamic physical work.

(a) *Anthropometric Measurement: **S**tump Length* is an important factor in attaining successful prosthetic rehabilitation in amputees. Stability of the stump-prosthesis complex is impaired in the case of a shorter stump. Thus, fitting prosthesis to an amputee with a stump which is very short often requires the use of different prosthetic techniques (Isakov et al., 1992).

(i) Stump length and the *thigh muscles* strength of the amputated limb are among the major factors influencing outcome of prosthetic rehabilitation of trans-tibial amputees. A short stump might interfere with success in prosthetic rehabilitation of trans-tibial amputees. An adequately long stump provides the amputee with a good proprioceptive feedback (Guerts and Mulder, 1992) resulting from both a large contact surface and good stability of the stump-socket unit.

Ultimate goal in the rehabilitation of amputees is to return the patient to an acceptable level of function. Stump length is the major factor determining stability of the transtibial stump inside the prosthetic socket and consequently the quality of standing and walking. Other important factors which influence the rehabilitation outcome of amputees are an optimal prosthesis fitting and strength of the quadriceps and hamstrings muscles controlling the knee of the affected limb (Klingenstierna et al., 1990). Although most transtibial amputees manage their activities of daily living and conduct a fairly active life, strength of the amputated limb thigh muscles are found to be significantly reduced, especially in amputees with a short stump.

Transtibial Amputation

- ***Very Short***: When less than 20 per cent of tibial length is present. This amputation may result from trauma. Results in a small-moment arm, making knee extension difficult.
- ***Standard:*** When between 20 and 50 per cent of tibial length is present. An elective amputation in the middle third of the tibia, regardless of measured length, provides a well-padded and biomechanically sufficient lever arm. At least 8 cm of tibia is required below the knee joint for optimal fitting of a prosthesis.
- ***Long:*** When more than 50 per cent of tibial length is present. This amputation is not advised because of poor blood supply in the distal leg

.

Stronger thigh muscles will improve standing balance and quality of gait, especially among those with a short stump. The stump of transtibial amputees is less active in the daily functions of standing and walking. In fact, atrophy of the thigh muscles of the amputated limb is often observed among such amputees ((Isakov et al., 1996). Jaeger et al (1995) noticed that, in transfemoral amputees the amount of asymmetry in gait has a relation with the stump length; the longer the stump length the lower the asymmetry.

Residual stump of transfemoral amputees is always enclosed in a socket, which is part of the prosthesis. Transtibia1 amputees might have a limit in walking capacity due to inadequate socket fitting with excessive pressure forces, shears (Zhang and Roberts, 2000), torques and friction between skin and liner (Sanders et al., 2000). Prominent bone, volume changes and pain add to the list of problems (Levy, 1995). In short stump amputees both sway area and sway velocity was found to be more than medium stump amputee. The sway velocity increased inversely with the increase in length of the stump (Lenka and Tiberwala, 2010).

Transfemoral amputations

- **Short:** Less than 35 per cent of femoral length is present. A larger weight bearing surface can be created if femoral transaction can be done at the level of the lesser trochanter. This level retains the femoral head and neck and the greater trochanter, resulting in improved prosthetic fit.
- ***Medium:*** When between 35 and 60 per cent of femoral length is present. Ideally, transfemoral limbs should be at least 4 inches or 10 cm above the lower end of the femur to allow room for the prosthetic knee. In a transfemoral amputation, both anterior and posterior muscular surfaces are well vascularized; therefore, equal flaps are fashioned.
- ***Long:*** When more than 60 per cent of femoral length is present but not capable of end bearing.

(ii) Length of the prosthesis: Being a weight bearing substitute for a lost part of the lower extremity, the prosthetic limb should be of correct length to fulfill its biomechanical task. The criteria for the optimal length of lower limb prostheses generally differ for below-knee and above-knee prostheses. A shortening up to two cm of above-knee prosthesis is generally allowed for ground clearance in the swing phase of walking. However, a shortening of not more than one cm, and for suction socket prostheses with minimal piston action only six mm or even less, has been suggested by Duthie and Bentley (1983). Recommendations to make a below-knee prosthesis full length and to avoid prostheses longer than the contra lateral lower extremity are probably in accordance with the current general opinion (http: //www.oandplibrary.org/poi/1984_03_124.asp).

(iii)Anatomical Concepts-Socket Shape and Orientation: The socket, as a human-device interface, should be designed properly to achieve tolerable load transmission, stability, and efficient control for mobility. Some early designs of the prosthetic socket, such as the "plug- fit," took the form of a simple cone shape, with very little rationale for the design (Mak et al., 2001).A long posterior flap for transtibial amputation is advantageous because it is well vascularized and provides an excellent weight-bearing surface. In addition, the scar is on the anterior border, an area that is subject to less weight bearing. The deep calf musculature is often thinned to reduce the bulk of the posterior flap. In a transtibial amputation, the fibula is transected one to two cm shorter than the tibia to avoid distal fibula pain. If the fibula is transected at the same length as the tibia, the patient senses that the fibula is too long; this may cause pain over the distal fibula. If the fibula is cut too short, a more conical shape, rather than the desired cylindrical shape in the residual limb results. The cylindrical shape is better suited for total contact prosthetic fitting techniques. A bevel is placed on the anterior distal tibia to minimize tibial pain on weight bearing. To avoid a painful neuroma, a collection of axons and fibrous tissue, nerves should be identified, drawn down, severed, and allowed to retract at least three to five cm away from the areas of weight-bearing pressure (faculty.ksu.edu.sa/72958/Documents/Amputation%20Levels.doc).

There are many functional details of socket shape and fit which make it possible for the amputee to derive and make most efficient use of the remaining hip musculature to control body movements and the prosthetic knee during the stance and swing phases of gait. When coupled with the proper alignment, proper socket shape has proved extremely beneficial to the average amputee. As with any method of fitting, variations in shape must be made in accordance with the muscular development and condition of the individual stump. The socket shape however, allows the ischial seat to be placed laterally to provide relief in the hamstring region and does not disturb the functioning of the limb during walking. After the general type of alignment has been decided upon, the necessary features can be incorporated into the orientation of the socket on the stump. The primary features required of a material to be used in making a suction socket are ease in forming to the proper shape, adaptability to a surface finish which is nonirritating and easy to keep clean, and ease in making alterations as required by changes in the stump (http://www.oandplibrary.org/al/1955_01_035.asp).

(iv) Special considerations in the suction socket: *Tightness of fit-.* The sockets have to be tight around the residual stump to avoid slipping; this causes additional discomfort to the amputee (Ramakrishna, 2014). In the case of the suction sockets; better results are obtained by having proper contours than by having a tight fit. The superior brim of the socket should fit the contour of the stump while the muscles are tensed, and the fit should be so accurate that the socket can be suspended for short periods by skin friction without the aid of negative pressure *(i.e.,* without a valve).

(v) Free Space below the Stump End: The volume of unoccupied space at the lower end of the suction socket is not critical in obtaining sufficient suction. In most cases, it is convenient to have approximately two inches of space below the end of the stump to provide room for installation of the valve and for elongation of the soft tissue. In general, the smaller the volume in the end of the socket the less the excursion, but in itself the amount of free volume has no significant effect on the magnitude of the negative pressure.

(vi) End Bearing: If it can be tolerated, end-bearing is recommended because it relieves the load on the ischium. Felt or foam-rubber padding placed in the bottom of the socket permits comfortable end-bearing, the thickness of the padding governing the amount of weight carried on the end of the stump. *Finish-* Non irritating finishes are preferred. Slipping of the socket is possible because of perspiration. In some cases, perspiration also has caused the lacquer finish to deteriorate and to produce a roughness resulting in skin irritation (http://www.oandplibrary.org/al/1955_01_035.asp).

(vii) Type of Stump: also influences the design of the prosthesis. A biomechanical study by Gottschalk et al. (1994) revealed that the loss of important groups of muscles, used for abduction and adduction in transfemoral amputees caused a loss of function in the hips and that preserving these muscle groups improved the walking conditions for amputees. They also proved that comfort level for the amputee is dependent on the amount of residual tissue. There are also residual stresses that are experienced in the stump as well, resulting in discomfort while walking (Schmalz et al., 2002). The stresses in the residual stump are a bi-product of asymmetric reaction forces and moments. A study conducted by Mattes et al. (2000) showed that as the mass and moment of inertia of the prosthesis approaches that of the intact leg the more asymmetric the gait becomes, therefore, expending more energy.

(b) Physiological aspects*: (i) Pressure Measurements and Alignment:* Alignment of the prosthesis is also identified as a factor to increase energy expenditure (Schmalz, 2002).

The asymmetries in alignment also give rise to postural asymmetries. Gaunaurd et al (2011) explained that leg length, pelvic inclination, and hip extension were different for the intact and the amputated leg. Rabufetti et al (2005) showed that transfemoral amputees adapt asymmetric pelvic tilt and joint angles at the hip as compensation strategies during gait. The goal of the asymmetric prosthesis is to alleviate any form of compensatory motions, which in-turn reduces the misalignments of the prosthetic joints during walking. All transfemoral prosthesis designs so far have the knee location matching the intact leg. To mitigate gait asymmetries, the asymmetric prosthesis is a simple and unique passive solution relying purely on tuning walking dynamics. Abnormal spatio-temporal distribution of *center of pressure* was identified as another reason for asymmetry in transfemoral amputee gait (Schmid, 2005). Spatiotemporal parameters include the measurement of step length, step width, walking speed and cycle time. Center of pressure of the prosthesis fails to shift towards the posterior during gait initiation and anterior during gait termination whereas ideally it should (Vrieling et al., 2008 and Vrieling et al., 2008).

(ii) Mobility-related assistive technology (MAT): Because of the physical impairment and decreased functional capacity resulting from the loss of one or more amputated limb and in addition to concomitant injuries sustained, amputees' use a wide variety of mobility related assistive technology. There are a variety of assistive devices to choose from. While safety is a primary factor in selecting an appropriate assistive device, mobility is a secondary consideration that cannot be overlooked. The criteria for selection should include (1) unsupported standing balance, (2) upper-limb strength, (3) coordination and skill with the assistive device, and (4) cognition.

Amputees will also require an assistive device while ambulating with the prosthesis. Gailey and Clark.(2015) states that, all amputees will need an assistive device for times when they choose not to wear their prosthesis or for occasions when they are unable to wear their prosthesis secondary to edema, skin irritation, or poor prosthetic fit. Utilization of secondary MAT is sometimes important for patients with comorbidities and can increase activity level. Any increase in activity level, even slight increases, can have positive health benefits (Sprunger et al., 2012). Generally, the higher the level of amputation, the harder it will be to adapt to prosthesis. Not only does a higher level of amputation create a much more unstable base, but also the added components to compensate for the knee joint make it a much more complicated event when relearning how to ambulate. Oxygen consumption and the efficiency of the body as a whole, are decreased depending on the level of amputation (Chin et al., 2010, Sansam et al., 2009 and Velzen et al., 2006).

2. Neuro Ergonomics: is a relatively new development which involves the application of more in-depth neurophysiological methods such as brain imaging techniques. This advanced methodology can be used for evaluating the customers' preferences for one or another design of human-computer interfaces or for a particular version of industrial products (Cañas 2011).

The ***P****ostural Steadiness* is the dynamics of the postural control system associated with maintaining balance during quiet standing and usually assessed by the displacement of the center of pressure (CoP) as indicated by Lenka and Tiberwala (2010).

Analysis of gait in trans-tibial amputees showed a shorter body weight bearing stance phase on the amputated limb as well as asymmetry in other gait phases (Baker and Hewison, 1990).

3. Cognitive Ergonomics is a sub discipline of ergonomics that studies the cognitive processes at work with an emphasis on an understanding of the situation and on supporting reliable, effective and satisfactory performance (Cañas 2011) like *Posture and Ambulation***.** Postural confidence is an initial precondition for all activities within the activity of daily living, thereby amputee patients are forced to create a new control strategy of postural stability and eventually, to adapt commonly used strategies (Viton et al., 2000). Training for a well -functioning standing posture is an important issue in the rehabilitation of persons with unilateral lower limb amputation (Wennerfeldt, 2013).

(a) Balance Confidence: Belief does not guarantee success; however, it can contribute to performance. Ultimately self-imposed restriction can lead to deterioration in balance, muscle endurance, strength, flexibility and coordination and therefore, a debilitating cycle, including further reduction in balance confidence, may exist (Miller and Deathe, 2004). Confidence in a person's balance has been shown to be an important predictor of social activity among people with lower limb amputations. This may better determine whether or not the individual will engage in their daily, social and physical activities. Reduced confidence in balance has been shown to limit societal participation, which can negatively affect long term function in the community. This reduced capability, mobility and participation in social activities can lead to a further development of

impairments that accompany inactivity, such as loss of muscle strength, loss of endurance and loss of balance capability (US National Library of Medicine, 2011).

Differences between groups based on the cause of amputation, because individuals with vascular disease tend to be older, have more co morbidity, and use more medications. Balance confidence would differ between people with amputations due to vascular and nonvascular causes as well as between people with transfemoral and transtibial amputations. Reduced mobility and balance following lower limb amputation is a significant issue affecting older patients with limb loss. Furthermore, there is no standard outcome measure to assess the effectiveness of such an intervention. This suggests that successful rehabilitation of an acute or chronic impairment extends beyond the acquisition of endurance, strength, range of motion, or learning about a new strategy. A reduction in balance confidence among individuals with a lower limb amputation seems logical given the gait related impairments, such as an altered gait pattern associated with the use of a prostheses, the loss of sensory feedback (proprioception), and altered postural sway (Miller and Deathe, 2004).

(b) Alignment of prosthesis: (i) *Center of Balance Reference Line:* The center of balance reference (CBR) line is a theoretical vertical line through the center of pressure that divides the individual in the sagittal plane into anterior and posterior parts (Breakey, 1997). There are actually two CBR lines to be considered. In static alignment of lower limb prosthesis, the load line is the preferred reference line. To determine optimal balance between the prosthetic and sound limb, however, both reference lines must be considered (Blumentritt, 1997). Exhibit - 7 clearly shows the fabrication and bench alignment of the prosthetic components in the three Centers in the design of the prosthesis

(ii) *Concept of moments:* A moment is defined as the tendency of a force to create rotation about a certain point. In prosthetic alignment it may be assumed that this point is located roughly in the geometric center of the prosthetic socket ("center of socket").

ALIGNMENT TECHNIQUE

Aligning every prosthetic device to a set standard bench alignment provides an ideal "starting point" for a prosthetic fitting. The socket produced is properly aligned with respect to both the residual anatomy of its intended wearer and to the rest of the prosthesis, including the prosthetic foot and the shoe to be worn over it (Fleer and Wilson 1962).

Fabrication of the plastic-laminate below knee or above knee socket involves the taking of a suitable impression (the negative cast) of the particular stump concerned; the preparation of a positive model (male replica) from the negative mold; modification of the model in such a fashion that in the final socket (to be made from the rectified model) the weight of the body will be distributed over the respective areas of the stump according to their relative tolerance, or lack of tolerance, for weight-bearing; and, finally, the layup, lamination, curing, and finishing of the plastic socket itself. In all cases, at least nine areas were identified including the patella itself.

Anatomical landmarks marked- During Impression of Stump

With the exception of those areas (around the patellar ligament, just under the lower edge of the patella, in the popliteal space, and so on), the positive plaster model now constitutes a faithful reproduction of the stump. It remains to revise the model in such a way that, when a socket is laminated over it, the shape of the socket will be that required to distribute the weight of the body over those areas best suited to weight-bearing while at the same time relieving sensitive areas from responsibility for bearing more weight than will be comfortable. This is accomplished by carefully carving away plaster where additional force transfer will be acceptable and by building up the model in areas expected to be incapable of accommodating any appreciable part of the load.

Checking with Laser **Socket alignment**

Aligning the components

For the above-knee prosthesis there were no simple recommendations for bench alignment. Bench-alignment prescription was not as straightforward as for the below knee patient, because an artificial knee joint had to be employed with the consequent difficulties of control over this mechanism

Exhibit- 7. Fabrication and Bench Aligning the Prosthetic Components

The socket may be considered to have a tendency to rotate about this point, and this rotation is resisted by the force applied by the residual limb stump (Weber and Don, et al. 1991). The prosthesis is subject to downward forces applied by the residuum from above, and by the reaction force from the ground below. If the downward force applied by the stump, and upward acting ground reaction force (GRF) are acting in the same line (collinear), there is no tendency for the socket to change its angular relationship with respect to the residual limb (rotate about the theoretical center of socket). If they are not collinear, there will be a tendency for the socket to change its relationship with respect to the stump (rotate). ***This tendency is best resisted with a good fitting total contact socket, and is influenced by the alignment of the prosthesis***. This described tendency of the socket to rotate about the limb in turn creates forces that act on the stump. Forces acting on the stump can be controlled so that relatively higher forces (pressure) will be applied to the areas where they are best accommodated and are most effective. These forces may also be reduced in pressure sensitive areas (Lannon, 2003).

If a prosthetic device is to give optimum service to the amputee, it must always be properly fitted, regardless of its mechanical excellence. This is especially true in the case of the lower extremity, where the prosthesis must function continually and where poor fit or alignment will lead quickly to rejection of the device by the wearer. Among prosthetist there seems to be general agreement that by far the most important factors in the success of any artificial leg relate to fit and alignment on the subject. Fit and alignment are usually considered together, since they are mutually interdependent. (http://corporate.otto bock.co.uk/cps/rde/xbcr/ob_uk_en/646F219-GB-11-1304w.pdf.)

Radcliffe (1977) presents the "*zone of voluntary stability*" as an essential component in the alignment of the transfemoral prosthesis. He explains that if the knee center is positioned within this zone, alignment stability in the sagittal plane will be achieved. Breakey (1998) suggests another zone to be considered in achieving the appropriate alignment of lower limb prosthesis. This is referred as the "*zone of integrated balance*" and defined as a zone in which the center of balance line as determined on the prosthetic limb of the total subject is compared to the center of balance line on the prosthetic side only." Breakey (1998) also suggests that the closer the approximation of this center of balance lines, the more integrated is the balance of the prosthetic side with respect to the overall balance of the amputee.

"Alignment" refers to the spatial relationship between the prosthetic socket and foot. The main purpose of alignment is to position the prosthetic socket with respect to the foot so that undesirable patterns of force applied to the residual limb are avoided. A second purpose is to produce a normal pattern of gait (home.ica.net/~cocinc/Alignment.html). Three alignment patterns are followed:

- Bench alignment
- Vertical Alignment Axis – VAA approach
- Anatomical Based Alignment – ABA theory

- *Bench alignment:* Taking the time to properly bench align prosthesis contributes to a smooth, energy efficient gait pattern. This includes controlled knee flexion after heel strike, smooth rollover with limited recurvatum (hyperextension), and heel off prior to initial contact on the normal (other) foot. In the sagittal plane, proper anteroposterior (AP) positioning of the socket with regard to the foot will result in even weight distribution between the heel and toe portion of the foot statically. For a transtibial prosthesis, a plumb line (gravitational line 90° to the ground) should fall through the center of socket Figure (13) (it may be easier to mark this with an erasable marker), slightly anterior to where the ankle joint axis, and through the weight bearing area of the foot between the middle of the weight bearing surface of the heel, and the metatarsal heads (Bowker et al., 2002).

Figure:13 Bench Alignment

- *Vertical Alignment Axis:* In the VAA approach, the socket center is defined as the geometric center of the cross-section of the socket at the patellar tendon bearing level. While the alignment reference center (ARC) is defined as the junction of the middle and posterior thirds on the longitudinal axis from the center of tip to the heel of the shoe tracing. In this approach, the socket axis is independent from the VAA and is determined by the subject, who wears the formed socket while bearing maximal weight on a padded stand in a most comfortable position. The socket center is aligned vertically over the supporting base, which is the shoe tracing (Yeongchi Wu, 2010)

The VAA technique is based on the principle that the socket center falls perpendicularly to the alignment reference center on the supporting base, which is created from the shoe tracing. This alignment approach differs from the traditional concept because it is based on the relationship between the socket center and supporting base, rather than the knee center and ankle bolt (Reisinger D.K 2007).

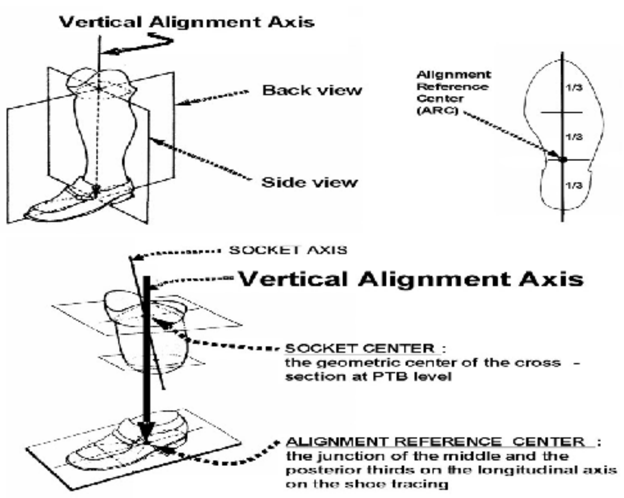


Figure:14 Vertical Alignment

☙ *Anatomical Based Alignment (ABA)* Anatomically-based-alignment (ABA) theory was developed based on the premise that the hip, knee, and ankle centers lie along a common axis during single leg support. The theory uses anatomical landmarks (greater trochanter and knee center) to determine where the ankle center (prosthetic foot bolt) should lie in the fabricated prosthesis. Two systems, a supine system and a standing system, were developed to help the prosthetist capture the correct alignment. The alignment bars that are provided with the ABA systems, and which are aligned with the anatomical landmarks, help guide the prosthetist on where to mark the alignment reference lines on the cast of the subject's residual limb. Length measurement based on the sound limb positions the ankle center of the prosthetic foot at the appropriate location on the axis and captures the prosthetic alignment. The marked cast is then used to fabricate monolimb prosthesis with an acceptable alignment for the amputee (Reisinger, 2007).

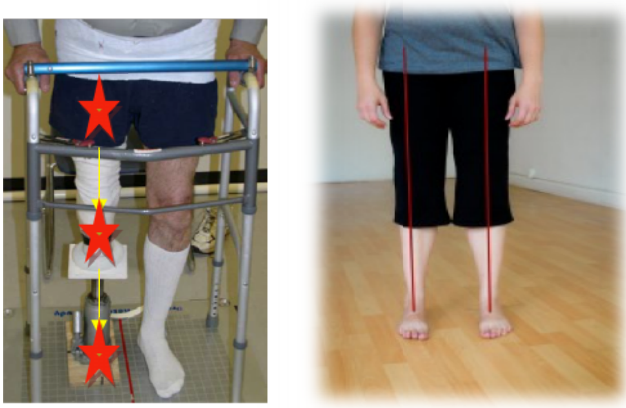


Figure: 15 Static alignment

The alignment of the prosthesis will in large measure establish the gait pattern of the amputee, assuming of course that the patient has been trained to use his prosthesis in a manner consistent with its alignment. A leg amputee can walk efficiently with a symmetrical, narrow based gait only if his prosthesis has been planned and constructed to achieve such a gait pattern. *The type of alignment also affects the manner of fitting the socket.* An amputee walking with a narrow base may require a distribution of contact forces between stump and socket entirely different from that of an amputee walking with a wide base *(i.e.,* abducted gait).

F. Status Quo-Accessibility of Limb Prosthesis

The major objective of prosthetics is to restore, as close as possible, the functional capacity formerly held by the person prior to amputation, while attaining the best result afforded to, and deemed necessary by the patient. On the surface, it would appear that there would be very little difference in the design and manufacture of prosthetic solutions. However, availability of materials, resources and skilled personnel, together with a variety of differences make amputees either adapt themselves to the prosthesis or reject them. The factors influencing the accessibility of prosthesis are as follows:

- **a.** Transtibial amputee with short stump develops pain and/or blisters or friction sores due to shear forces as a result of instability of the stump-prosthesis complex (Seliktar et al 1980 and Nissan, 1977).
- **b.** Presence of pressure ulcers, friction, allergic dermatitis or volume changes leading to improper socket fit (Aström and Stenström 2004)
- **c.** Improper maintenance of prosthesis leading to skin problems such as allergic contact dermatitis, follicular hyperkeratoses, verrucous hyperplasia and infection (Lyon et al., 2000).
- **d.** Residual stump being affected by sweat and friction in the socket leads to skin sores and other dermatological complications (Dudek et al., 2005).
- **e.** Back, hip, and knee problems caused by an ill-fitting socket (www.amputee-coalition.org/inmotion/sep_oct.../prosthetic_sockets).
- **f.** Joint pain and back pain due to improper shift of body weight to the unhealthy contralateral limb can cause osteoarthritis leading to rejection of prosthesis (Levy, 1995).
- **g.** Burning sensation while sitting because the hamstring attachments attempt to stretch over an ischial seat located high or medially, especially when the ischial seat has been placed diagonally across the posteromedial apex (www.posna.org/news/amputations.pdf).

h. Slightest change in weight or muscle mass changeS the alignment and cause problems with residual limb. For a new amputee, the residual limb changes so rapidly in a temporary prosthesis that the alignment may require weekly updating and changing of prosthesis is expensive (http://www.amputee-coalition.org/inmotion/sep_oct_06/ prosthetic-socket.html).

i. Individuals learning to use ultra modern prosthetic leg after amputation fail to achieve their potential. Sophistication is a constraint (Miller and Deathe, 2004).

j. High tech assistive robotics, where technologies are being developed to actively aid or restore locomotion to individuals are not affordable due to its high cost (Tucker et al., 2015).

k. Limitations in the effectiveness of assistive devices and limited access to follow-up services and repairs were issues desired to be addressed (Magnusson et al., 2014 and Magnusson, 2013).

l. Socket fracture was reported by a large number of subjects, Innovations in technology by manufacturers can help reduce these kinds of failure (Sprunger, 2012).

m. Therapy programs extended for balance training following prosthetic training is not standard practice due to limited resources for long term therapy (Clark and Gailey, 2015).

The innovations in new technology are meant to address the problems associated with everyday prosthetic use and ultimately decrease the rate of abandonment of the device. Abandonment of the prosthesis can be due to several factors. According to Gauthier-Gagnon et al., (1993) 31 determinants for abandonment of the device include "predisposing" conditions like age and level of amputation, reinforcing factors, quality of fit, satisfaction, cosmesis, mass properties of the prosthesis, comfort, and function. *Failure to provide a satisfactory alignment* may result in problems for the amputee, *such as difficulty in walking, stump pain, or tissue breakdown.* It is therefore important to make every endeavor to provide an acceptable alignment to the patient on every occasion that the need arises and that the alignment arrived at be the "optimum alignment." During the phase of dynamic alignment, the prosthetist observes the gait of the amputee and listens to the patient's comments. (Zahedi et al, 1986).

Thus physiological and psychological rehabilitation and social support related aspects are projected to have a say in the accessibility and adaptability of prosthesis by the affected population. The plan and procedure of this study, the methodology of which is given in the next chapter is drafted to locate the strengths and weakness for prosthesis adaptation by a selected group of amputees in a small geographical area.