Analysis of Upper Limb Prosthetic and BMI Data in Atlantic Canada

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Abstract

This research used a quantitative method of approach and the study design was cross sequential in nature and retrospective since data used dates back to 1981. This study examined both the demographics of the total population and anthropometric data from a subset of working age group at the Atlantic Clinic for Upper Limb Prosthetics. The clinic population of 212 clients was adult dominated with the majority being males. Over the years, myoelectric prostheses have become the preferred choice of prosthesis for most of the clinic clients. This study has shown that older clients visited the clinic less frequently for fit issues compared to younger clients and they spent fewer days per clinic visit as well. This study also showed that a high proportion (77.8%) of the clinic subset population with acquired limb loss have BMIs above the overweight border-line indicating the need for more awareness of the health implication of being overweight.

Dedication

To the Almighty God who has made it possible for me to come this far and to family without whose support and effort I could not have made it.

Acknowledgement

This has been a long journey which would not have been possible without the help of many people in diverse ways. Everyone who has contributed to my stay in Fredericton consider yourself heartily thanked.

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Glossary

BMI - Body mass index

Degrees of freedom - The set of independent displacements and/or rotations that specify completely the orientation of a body.

Distal - Situated away from the point of origin or attachment, the terminal end.

IBW - Ideal Body weight

NHS Choices – UK's online 'front door' to its National Health Service.

Prehensile – Grasp

Pronation – Rotation of the hand or forearm so that the palm faces down or back.

Prosthesis - An artificial replacement for a body part.

Prosthetist - The practitioner who deals with prescribing, fitting and adjusting prostheses

Prosthetics - The profession of artificial limbs

Range of motion - The total amount the articulating portions of a joint or prosthesis can move.

Residual limb - The remaining part of the limb after amputation.

TBW - True body weight.

Terminal device – Distal portion of prosthesis, often replacing hand function or appearance.

Introduction

The loss of body parts can have distinct but overlapping psychological consequences (Maguire, 1998). Thus, limb loss is a physically and psychologically devastating event that can happen to a person. Flannery & Faria (1999) defined limb loss as the experience of parting with a limb of the body and a tragic event in certain situations where amputation is inevitable. Amputation causes major body disfigurement, it renders people less mobile, influences their participation in activities and quality of life and puts them at risk for loss of independence (Gitter & Bosker 2005; Burger & Marinček, 2007). Amputation is a triple threat that involves loss of function, loss of sensation, and loss of body image (Racy, 2002; Østlie et al. 2011). Hence, it affects people physically, psychologically, socially, and economically (Dudkiewicz et al., 2004; Davidson et al., 2002; Racy, 2002).

Worldwide prevalence estimates of amputation are difficult to obtain, mainly because amputation receives very little attention and resources in countries where survival is low but the problem remain very real in every country (Aleccia, 2010). Globally, the rate of amputation has been on the rise due to accidents, gun- shot injuries, vascular diseases, diabetes, terrorist attack and earthquakes (Soomro et al., 2013). The World Health Organization (WHO) estimates that in Africa, Asia and Latin America combined, as many as 30 million people require prosthetic limbs, braces and other such devices for daily living, up from 24 million people in 2006 as result of limb loss (Aleccia, 2010).

In the United States, about 1.6 million people live with limb loss and an estimated 185,000 persons undergo an amputation of an upper or lower limb each year (Ziegler-Graham et al., 2008). Upper limb traumatic amputations occur twice as frequently as traumatic amputations of lower limbs. In 1984, major upper limb amputations (excluding thumb and fingers) made up 15% of all acquired major limb amputations in the United States. Acquired upper limb loss was more common in males between the ages of 15-45 and for 75% of these cases the cause was trauma (Martin & Edeer, 2011).

Dillingham et al. (2002) studied nationally representative hospital discharge data from 1988-1996 in the United States with similar results. About 70% of all upper limb amputations were trauma-related and most were below the elbow. Although trauma-related amputations are decreasing compared to disease-related amputations (the annual incidence rate in the US of trauma-related amputations dropped from 11.37 to 5.86 per 100,000 persons between 1988 and 1996), they still constitute the majority of upper limb amputations. Usually, the young, active, and economically productive people are affected by traumatic amputations (Martin & Edeer, 2011; Dudkiewicz et al., 2004). In Denmark, a study by Kejlaa (1992) indicated that upper limb amputations were 3% of all amputations and 74% were trauma-related, generally occurring in unskilled or skilled industrial jobs, and in traffic accidents.

Martin & Edeer, (2011) stated that in 1986, in the UK, upper limb amputees were about 17% of the total amputee population. In New South Wales, Australia, major upper limb amputations accounted for 5-6 % of all major amputations in the period 1991-1994, and the rate of trauma-related amputations amongst all major upper limb amputations increased from 49% to 57%, from 1991 to 1993. A descriptive study from England reported upper limb amputations due to accidents to be double the number compared to disease-related ones (in the 1958-1988 period), and the majority of them occurred in industrial accidents. Also in a survey of Australian upper limb amputees, Davidson

(2002) reported that 31% of 70 respondents were transradial, 23% were transhumeral, 4% were forequarter and 10% were wrist amputees. In an urban area in Finland, in 1984-1985, the rate of major upper limb amputations, which required prosthetic application, was 0.3 per 100,000 persons per year. Bhaskaranand et al. (2003) studied upper limb amputees fitted with prostheses in India, and in the result 66% were below-elbow amputees. The latter two studies are surprising slightly different from results of earlier studies mentioned above. Interestingly, the time period of the Atlantic Clinic for Upper Limb Prosthetics data to be used in this research is from 1981 to present which covers a similar time range to the studies above.

Currently, no comprehensive data source exists from which to produce accurate annual estimates on the incidence of limb loss and current prevalence of limb loss within Canada (Amputee Coalition of Canada).

A study by the US National Limb Loss Information Centre (NLLIC) in 2008 and Smith (2006) indicated that in the US amputations are dysvascular, trauma, cancer, or congenital related. Each year, the majority of new amputations occur due to complications of the vascular system (of or pertaining to the blood vessels), especially from diabetes. These types of amputations are known as dysvascular. Amputations due to vascular disease problems associated with the blood vessels accounted for the majority (82%) of limb loss discharges and increased from 38.30 per 100,000 people in 1988 to 46.19 per 100,000 people in 1996. Lower-limb amputations accounted for 97 percent of all dysvascular limb loss discharges with 25.8% at above-knee level.

Upper-limb amputations accounted for the majority (68.6%) of all trauma-related amputations occurring during the study period. Males were at a significantly higher risk for trauma-related amputations than females. Limb amputations resulting from cancer most commonly involve the lower limb; above-knee and below-knee amputations alone accounted for more than a third (36%) of all cancer-related amputations. There were no notable differences by sex or race in the age-specific risk of cancer-related amputations, though rates of limb loss due to cancer were generally lower among African Americans.

Rates of congenital limb anomalies among newborns were at 26 per 100,000 live births, relatively unchanged over the study period. Upper-limb differences accounted for 58.5% of newborn, congenital limb anomalies. Although rates of cancer and trauma-related amputations are decreasing, rates for dysvascular amputations are on the rise. Incidence of congenital (present at birth) limb difference has seen little or no change.

Independent of the cause of amputation, whether it is due to vascular, traumatic or orthopaedic causes, it is a mutilating surgery and it definitely affects the lives of these patients (De Godoy et al., 2002). Limb loss can be a psychologically stressful experience, rates of depressive disorders among persons with limb loss range from 21-35% compared to estimates of 10-15% in the general population (Williams et al., 2004).

Individuals with an amputation are faced with adapting to several losses and changes to their lifestyle, social interactions and identity (Horgan & MacLachlan, 2004). The loss of an upper limb potentially has a greater impact than lower limb, this is because the role of the hand in human life is not limited to physical/functional movements, but, rather, is intimately intertwined with psychosocial roles including gestures, caressing, communication, and sensation (Martin & Edeer, 2011; Saradjian, Thompson & Datta, 2008).

Living with an upper-limb difference or experiencing an upper-limb amputation requires developing unique approaches to both the small and large tasks that life presents each day (Ryan, 2012). Ryan further states that when you consider the intricacy of the human hand and the multitude of movements and grips it performs, it is clear that upper-limb patients have very specific rehabilitation needs. Working with a prosthetist and an occupational therapist who specialize exclusively in upper-limb patients and their rehabilitation can improve an amputee’s abilities and increase their independence.

Many parameters are involved in the successful rehabilitation of upper limb amputees. One should consider the reason for the amputation, the type of prosthesis, the level of the amputation, dominance, time interval between amputation and rehabilitation, and pain (Dudkiewicz et al., 2004). Successful rehabilitation after upper limb amputation requires a multi-dimensional, interdisciplinary approach (a comprehensive team of healthcare professionals) (Martin & Edeer, 2011). The comprehensive team of healthcare professionals must also address issues such as emotional concerns, social adjustment and integration, and nutrition and physical fitness (Ryan, 2012). Selection of the appropriate prosthetic device that provides the best prehension and functional movement is an important goal of rehabilitation. The amputee‘s physical and cognitive capacity (e.g. amputation level, residual muscle capacity); functional, recreational and vocational needs, psychosocial acceptance, availability of resources (e.g. health care system, insurance coverage), accessible medical/technical support for prosthetic fitting and follow up (e.g. living in rural or urban areas) influence the prosthetic choice (Martin & Edeer, 2011).

With a background in nutrition, another focus of the researcher in this study is finding out how the body mass index (BMI) of a person with upper limb loss will play a key role in the rehabilitation process. To be able to assess the nutritional status of persons with limb amputation, their BMI needs to be calculated which is dependent on body weight and height. Since body weight generally reflects many physical attributes (size and shape) of the human body, it becomes an important physical characteristic that can be helpful in making clinical assessments, especially during amputation and prosthesis fitting.

The Atlantic Clinic for Upper Limb Prosthetics specializes in fitting myoelectric prostheses; however, they also offer other types of fittings such as cosmetic restorations, passive prostheses, body powered prostheses, recreational adaptations, or specially designed custom prosthetic devices. The type of fitting is determined based on the desire of the client and family, the client's lifestyle and vocational interests as well as funding considerations.

Each client (infant, child, adolescent or adult) is assessed at a clinic with one of three physiatrists (specialists in physical medicine) as well as the clinic prosthetist and occupational therapist. Following the clinic appointment, a plan is made for fitting prosthesis or prosthetic device which best meets the client's needs (Wendy Hill, Atlantic Clinic Occupational Therapist). The clinic has patients visit records going back to 1981.

Research Question

With a focus on clinic data over a period of 30 years, the research questions to be addressed include;

1. What is the description of the Atlantic Clinic population?
2. What transition has taken place in the type of devices being provided over the period of 30yrs?
3. What factors influence prosthesis choices?
4. What is the effect of BMI in achieving better outcomes in upper limb amputees?

Hypothesis

1. Body overweight leads to longer delays before first prosthesis fitting and fit issues for acquired amputees.
2. Acquired amputees have more difficulty in controlling body weight than those with congenital limb loss.

Purpose of the Study

The aim and purpose of this research are to;

1. Determine which groups of amputee have weight problems and whether BMI affects the time from amputation to first prosthesis fitting.
2. Determine the pattern of visits, frequency and duration; changes in prescribed devices and cost over time.
3. Determine pattern in patients' choice of prosthesis and whether this has changed over time; and changes with time or age over the use of sports adaptations or other devices.
4. Determine whether the percentage corresponding to amputation levels or reason for amputation is similar to the literature.

Literature Review

Upper limb amputation, as the result of trauma, disease or congenital malformation, is a problem that will lead to a certain level of functional disability. The rehabilitation process can be fraught with difficulties, both physical and emotional. Most amputees do very well given resolve, motivation, perseverance and the aid of a large multidisciplinary team (Jain & Robinson 2008). This literature review will focus on the structure of upper limb, upper limb amputation, types of prosthesis, rehabilitation of upper limb amputation and the role of nutrition in rehabilitation.

The Upper Limb

The basic understanding of the anatomy of the human arm is very important since this demonstrates clearly that upper-limb amputee patients have very specific rehabilitation needs (Ryan, 2012). As shown in figure 1, the human upper arm includes three joints: the wrist, elbow, and shoulder and provides seven mechanical degrees of freedom. The shoulder complex (including the clavicle) provides three degrees of freedom, the elbow joint provides two, and the wrist provides two (Chan, 2012). The clavicle is an "S" shaped bone located between the sternum and the scapula, it articulates medially with the manubrium of the sternum and laterally with the acromion process of the scapula. The clavicle forms a strut that supports the upper limb and it is the first bone to begin ossification during development, however it is frequently fractured (Tank, 2009). The Scapula is the bone of the shoulder and floats in a sea of muscles, so it is difficult to fracture. The scapula articulates with only one bone (the clavicle) at the coracoclavicular and acromioclavicular joints (Tank, 2009).

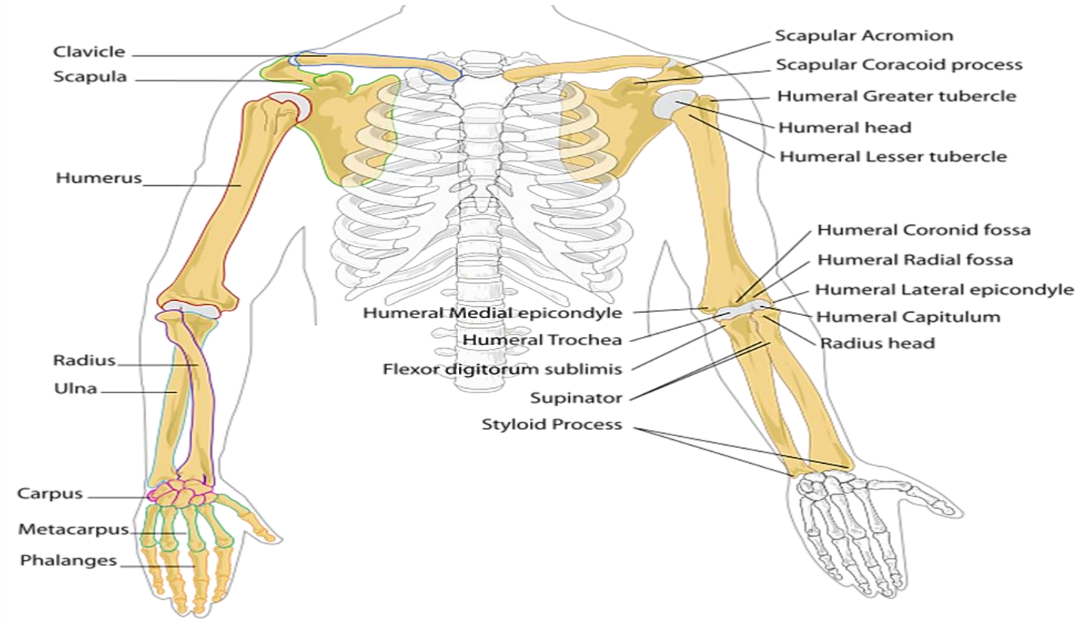


Figure 1: Bone Structure of Human Arm (Wikimedia Commons Contributors, 2008)

The bones of the arm include the humerus, radius and ulna, the latter two of which are the forearm bones (Craig 2011; Tank, 2009). The humerus is the bone of the arm (brachium) which articulates proximally with the scapula at the glenoid fossa and it also articulates distally with the radius and ulna at the elbow joint (Tank, 2009). The ulna is the bone on the medial side of the forearm (antebrachium) and articulates proximally with the trochlea of the humerus and the head of the radius, it also articulates distally with the ulnar notch of the radius. The radius is the bone on the lateral side of the forearm (antebrachium). The radius pivots on its long axis and crosses the ulna during pronation.

The carpal bones are the bones of the wrist and metacarpal bones are the bones located between the carpal bones and the phalanges of the hand. There are a total of five metacarpal bones in the hand; the metacarpals of the four fingers are bound together by ligaments to form a firm foundation for finger movements; the metacarpal of the thumb is more independent in its range of motion. The phalanx (phalanges) are the distal two or three bones in the digits of the hand. There are a total of 14 phalanges in the hand; the thumb has two phalanges (proximal and distal) and each finger has three phalanges (proximal, middle and distal); phalanx means "line of soldiers" (Tank, 2009).

The muscles of the arm allow various movements such as flexion and extension of the elbow, supination and pronation of the forearm and flexion, extension, adduction and abduction of the entire arm, the wrist and fingers (Incledon 2004; Craig 2011). The muscles acting in tension around joints cause these movements: as the tension on one side increases more than that on the other side, a moment is caused at the joint, resulting in motion (Tank, 2009; Craig, 2011). When considering individuals with a limb deficiency, it is important to note that skeletal and muscular anatomy will differ. It is difficult to determine exactly how the anatomy differs, especially with congenital defects (Craig, 2011).

Upper Limb Amputation

Amputation is a surgical procedure for removal of part or the whole of a limb (Jain & Robinson, 2008). Upper limb amputation involves removal of all or part of the fingers, hand, forearm, upper arm or shoulder. There are many levels of upper extremity amputations, and with each one comes a different method of rehabilitation as well as a different type of prosthesis (Capital Health of Nova Scotia). Figure 2 below shows the major categories of upper limb amputations.

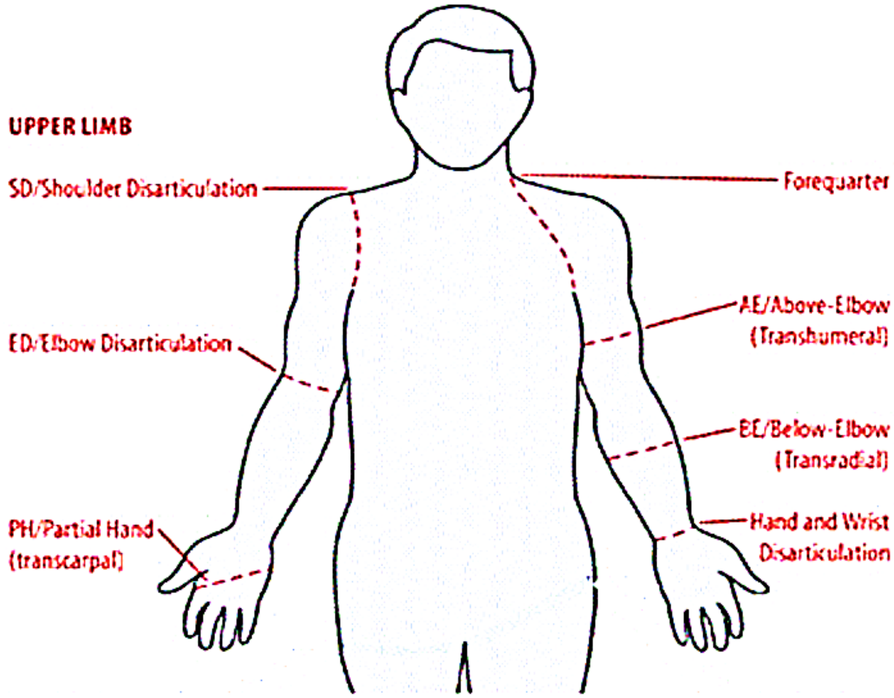


Figure 2: Categories of Upper Limb Amputations (Atlantic Canada Upper Limb Prosthetic clinic)

Hand and Partial-Hand amputation refers to the finger, thumb or portion of the hand below the wrist. Wrist Disarticulation is when the limb is amputated at the level of the wrist. Transradial (below elbow amputations) refers to amputation occurring in the forearm, from the elbow to the wrist whereas Transhumeral (above elbow amputations) refers to amputation occurring in the upper arm from the elbow to the shoulder. Shoulder Disarticulation is amputation at the level of the shoulder, with the shoulder blade remaining. The collarbone may or may not be removed. However, Forequarter amputation refers to amputation at the level of the shoulder in which both the shoulder blade and collar bone are removed (Capital Health of Nova Scotia).

The relative frequency of amputations at different levels in the upper limb reported by Jain & Robinson (2008) are forequarter (2%), shoulder disarticulation (5%), trans-humeral (28%), elbow disarticulation (0.3%), trans-radial (19%), wrist disarticulation (2%), partial hand (19%) and digit (22%). Watve et al, (2010) also reported the relative frequency of amputations at different levels in the upper limb to be upper digits 27%, partial hand 14%, wrist disarticulation 1%, transradial 18%, elbow disarticulation 1%, transhumeral 25%, double upper amputation 4%, forequarter amputation 4%.

According to Jain & Robinson (2008), the most common causes of upper limb absence are heredity, conditions at birth (congenital); or surgical removal for traumatic, malignant or vascular reasons. Compared to lower limb amputation, upper limb deficiency is often relatively more functionally disabling due to the fine motor tasks carried out by the hand and arm. Jain & Robinson (2008) further indicated that human beings after amputation adapt very well, however the contralateral upper limb takes over most of the tasks and becomes the dominant limb. The level of amputation will largely determine the degree of functional disability, that is, the impact on quality of life and the ability to carry out tasks of daily living.

The upper limb accounts for only 3-15% of all amputations and tends to be less common (Jain & Robinson, 2008) but can affect people of all ages (Capital Health of Nova Scotia). Kelly (2013) indicated that reasons for an upper extremity amputation vary, but they can be correlated by age range. Kelly further stated that correction of a congenital deformity or tumor is commonly seen in individuals aged 0-15 years, whilst trauma is the most common reason for amputation in patients aged 15-45 years, with tumors being a distant second. Upper extremity amputations tend to be rare in patients who are older than 60 years, but they may be required secondary to tumor or medical disease (Kelly, 2013). Jain & Robinson (2008) also indicated that the major reasons for amputation in the upper limb are trauma (43%), congenital absence (18%), and cancer (14%).

Trauma

Most upper limb amputations result from a traumatic event (WHO, 2004). Typically, an individual has little or no warning of the impending loss (Lake & Dodson, 2006). Traumatic amputations account for the majority of upper extremity amputations (68.6%) (Freeland & Psonak, 2007). Jain & Robinson (2008) in their article on Upper Limb Amputation stated that both the civilian and the military population are exposed to circumstances in which crush injuries to limbs can occur, and both populations have an identical risk of sustaining those injuries. Another common mechanism of injury is as a result of road traffic accidents, and again both military and civilians are at similar risk. Crush injuries can be associated with substantial damage to the soft tissues surrounding the bones. In recent years, Health and Safety regulations in the workplace have become more stringent and a subsequent decline in this type of trauma has been reported.

Jain & Robinson further indicated that war injuries, as seen in the Armed Services, frequently result in extensive soft tissue damage, in some cases without gross injury to the skin. People handling explosives are more likely to sustain upper limb injuries, facial and eye injuries. Both the extensive damage and the contamination complicate the treatment of these wounds. At present there are at least 75 countries in the world where significant minefields with anti-personnel devices have been laid. These minefields are producing large numbers of civilian casualties (15,000 to 20,000 per year in 2004), often in the poorest countries around the world.

The severity of the injury involving the bones, muscles, nerves and blood vessels of a limb will determine the chances of successful repair. In those cases where the bones are exposed to the outside environment, and where blood vessels and nerves are severely damaged, the surgeon may have no option but to amputate part of the limb.

Frostbite is another common cause for tramatic upper limb amputation, especially of the fingers (Jain & Robinson, 2008; WHO, 2004). Frostbite refers to the clinical situation where water molecules freeze and crystallise within biological tissue, resulting in the death of cells and tissue. If deeper structures such as bone are involved amputation might be required.

Limb deficiencies at birth.

Congenital malformation accounts for a small portion of reported amputations (up to 3 % of reported limb loss) (WHO, 2004). There are numerous congenital conditions in which newborns exhibit limb deficiencies of varying severity (Jain & Robinson (2008). In these cases a child is born with an abnormally shortened, malformed limb or no limb at all (WHO, 2004). The cause of congenital limb deficiency in most children is not known (Jain & Robinson, 2008; Smith, 2006). However, congenital causes are generally categorised as: genetic (inherited); vascular (related to blood supply); and related problems during pregnancy (Jain & Robinson, 2008). Depending on the extent of malformation the limb is surgically removed or the shortened limb is treated like an amputation and an artificial limb may be applied (WHO, 2004).

Diseases

The major diseases that contribute to amputation are vascular diseases, diabetes and tumors. In industrialized countries like the United States and Denmark, disease causes approximately 65% of all amputations performed each year unlike many developing countries where trauma is the main cause of amputation (WHO, 2004). Malignant tumours of the bones and soft tissues, such as osteosarcoma, chondrosarcoma and Ewing's sarcoma, are relatively rare cancers. In a study by Jain & Robinson (2008), they only represent approximately 1% of all cancers diagnosed in the UK; about 2,000 cases a year. In contrast to many other types of cancer, bone and soft tissue cancers have a relatively high prevalence among the younger age groups (20-40 year olds). In some cases surgical resection in the form of amputation is indicated. However, patients will often be treated with a combination of chemotherapy, radiotherapy and surgery. Shoulder and forequarter amputations (amputations at the level of or including the shoulder joint) are the most common procedures performed.

Most of the remaining upper extremity amputations occur owing to malignant tumors, congenital disorders, and vascular disease. Wright et al. (1995) indicated in the study report of 135 upper extremity amputations, that 84% occurred in men and 16% in women. Of these, 44% were below-elbow, 40% above-elbow, and 16% were shoulder disarticulations or forequarter amputations. The incidence and prevalence of below-elbow amputations in women may increase commensurate with their increasing number working at factory jobs (Freeland & Psonak, 2007). There are many factors that determine how much of the limb is amputated. Generally, the longer the remaining limb and the more joints that are kept intact, the easier it is to be fit with and use a prosthesis (Capital Health of Nova Scotia).

A number of studies (Magermans et al., 2005; Chan 2012) were conducted to quantify the upper extremity motions during activities of daily living. In a very simple model, the ranges of motion of the upper arm are tabulated in Table 1. It is important to note that the quantitative ranges listed in the table are for reference only as these values are different for different individuals. When considering a prosthetic prescription, it is often more important to allow the amputee to achieve desirable functional outcomes than to replicate the ranges of motion before amputation (Chan, 2012). The table below is a guide for the range of motion;

Table 1: Range of Arm Motion and Prosthetic Replacement from a Neutral Position (Chan, 2012).

Joint	**Motion**	**Range (Degrees)**	**Prosthetic Replacement Examples**
Wrist	Flexion/Extension	0−60/0−60	friction wrist
	Radial/Ulnar Deviation	0−20/0−30	
Elbow	Flexion/Extension	90−140/0−90	Body Powered elbow with lock; electric elbow
	Pronation/Supination	0−80/0−80	friction wrist; electric wrist rotator
Shoulder	Flexion/Extension	0−180/0−50	mainly passive prostheses
	Abduction/ Adduction	0−180/0−50	
	Internal/External Rotation	0−90/0−90	

The functional activities of the hand are extensive but can be categorized into prehensile and non-prehensile activities. Non-prehensile activities include pressing, tapping, lifting, pushing, stirring, touching, feeling, etc. Prehensile activities are grips which can be grouped into precision and power grips. A precision grip involves the radial side of the hand with involvement of the thumb, index, and middle fingers to form a jaw chuck. An example of a precision grip is holding a ball (Figure 3. left), or holding a scalpel in precise cutting. A power grip involves the radial and ulnar sides of the hand; all fingers including the little and ring fingers are recruited in a power grip. The thumb plays an important role in this grip. A typical power grip is the cylindrical grip. An example of such is holding the handle of a tool in which all fingers are flexed maximally (Figure 3. middle). When more power is needed in the power grip, the thumb is wrapped around the flexed fingers (Figure 3. right).

(Precision grip) (**Power grip)** (**More power grip)**

Figure 3: Prehensile Grip Patterns (Chan, 2012)

Upper Limb Prostheses

Upper limb prostheses are devices designed to replace, as much as possible, the function or appearance of a missing upper limb. Whereas upper limb orthoses are devices designed to support, supplement, or augment the function of an existing upper limb (Kelly 2013). Chan, (2012) indicated that the surgical procedure of amputation involves damaged tissue removal, bone beveling, residual nerve fiber transection, and muscle preparation (myodesis or myoplasty). In the procedure, an extra flap of skin is retained to close off the wound of the residual limb. After the surgery, a protective dressing will be applied to protect and gently compress the residual limb. A drainage tube may be placed initially to remove fluid from within the bandage. Once the initial dressing is removed, a shrinker sock or elastic bandaging will be applied to decrease swelling and promote shaping for future prosthetic fitting. The residual limb will continue to change shape and decrease in size over a period of six to twelve months before it will be stabilized. Repeated adjustments and refitting of prosthetic sockets are common during this period of stabilization.

Types of Prosthesis

Upper limb prosthetic devices are either passive or active (Martin & Edeer 2011). Passive prostheses, with no moving parts, are generally used for cosmetic purposes. Active prostheses may be body-powered or externally-powered. Hybrids of these two systems are also available. A body-powered prosthesis usually employs a harness and cables. A variety of terminal devices (hooks, hands) can be attached (Martin & Edeer, 2011). The continuum of prostheses ranges from mostly passive or cosmetic types on one end to primarily functional types on the other. The primary purpose of wearing a cosmetic prosthesis is to create the aesthetic look of a real limb (Chan, 2012), but they are often more difficult to keep clean, can be expensive, and usually one must sacrifice some function for increased cosmetic appearance (Kelly, 2013).

Cosmetic prostheses are not designed to provide much functional capability (Watve et al, 2010). However, an amputee may use a cosmetic prosthesis to assist the sound limb in carrying out some activities such as pushing a door open or steadying a piece of paper when writing (Chan, 2012; Watve et al, 2010). Cosmetic prostheses require the least harnessing and are the most lightweight of the three types (Chan, 2012).

Functional prostheses generally can be divided into the body-powered prostheses (cable controlled) and externally powered prostheses (electrically powered) (myoelectric prostheses, switch-controlled prostheses) (Kelly, 2013).

Body-powered prostheses

Body-powered prostheses (cables) are usually of moderate cost and weight. They are the most durable prostheses and have higher sensory feedback. However, a body-powered prosthesis is more often less cosmetically pleasing than a myoelectrically controlled type is, and it requires gross limb movement (Kelly, 2013). A body-powered prosthesis uses a cable and harness system to convey movement from another part of the patient's body to actuate the prosthesis (Watve et al, 2010; Kelly, 2013). For example, in a body-powered cable hand system, pulling a cable attached to a lever on a prosthetic hand by shoulder exertion can open the prosthetic hand (Chan 2012).

Externally powered prostheses

Instead of using body power, an externally-powered prosthesis uses an external power source to produce the work. An example of an externally-powered prosthesis is a battery-powered electric elbow (Chan, 2012). A switch operated by the amputee will activate the electric motor to create elbow flexion or extension. Prostheses powered by electric motors may provide more proximal function and greater grip strength, along with improved cosmesis, but they can be heavy and expensive (Kelly, 2013; Watve et al, 2010). Currently available designs generally have less sensory feedback and require more maintenance than do body-powered prostheses (Kelly, 2013). Externally powered prostheses require a control system. The 2 types of commonly available control systems are myoelectric and switch control (Kelly, 2013).

Both body-powered and externally-powered prosthetic systems have their advantages and disadvantages. Body-powered systems are usually lighter and more robust, but require more harnesses. Although it is not direct, pulling on the cable by a muscle group provides sensory feedback to the user. Externally-powered prostheses are often more aesthetic, require less harness, and have the advantage that their functional power is not restricted by their operating body movement. Their disadvantages are that they are usually heavier and cost more than body-powered prostheses (Chan, 2012).

Myoelectrically controlled prostheses use electrical signals from skeletal muscle contractions as control signals and are called myoelectric prostheses (Chan, 2012). They function by detecting electrical activity from select residual limb muscles, with surface electrodes. The signals are used to control electric motors (Kelly, 2013).

Switch-controlled, externally powered prostheses utilize small switches, rather than muscle signals, to operate the electric motors. Typically, these switches are enclosed inside the socket or incorporated into the suspension harness of the prosthesis. A switch can be activated by the movement of a remnant digit or part of a bony prominence against the switch or by a pull on a suspension harness (similar to a movement a patient might make when operating a body-powered prosthesis). This can be a good option to provide control for external power when myoelectric control sites are not available or when the patient cannot master myoelectric control. Many contemporary myoelectric control systems allow for the use of proportional control so that the speed of the component or terminal device activation varies with the intensity of the muscle contraction (Kelly, 2013).

A study by LeBlanc (1988) comparing prosthetic use in different countries shows the effect of cultural and psychosocial factors along with functional needs on prosthetic choices. According to this study, 72% of upper limb prosthesis users in the US preferred hooks as a terminal device; whereas in three European countries this percentage was lower, varying between 12-30% (Martin & Edeer, 2011).

According to LeBlanc (1988), 28% of prehensors in use in the US were hands (both passive and active); whereas in the UK, West Germany and Sweden the percentage of hand prehensors were 76%, 88%, and 70%, respectively. The advantages of body-powered prostheses include: simple operational mechanisms with intrinsic skeletal movement (which voluntarily opens/closes a terminal device), silent action, light weight, moderate cost, durability and reliability, and rough sensory feedback about the positioning of the terminal device. They are utilized more often in less-developed countries with scarce medical and rehabilitation infrastructure and technical resources. Bhaskaranand et al., (2003) pointed out that prosthetic rehabilitation of patients with financial constraints requires durable and low cost prostheses. Body-powered prostheses are also preferred by amputees living in rural areas (far from prosthetic centres), as well as by workers who are in labour-intensive manual and outdoor occupations. In general, prostheses used at challenging work environments are at a higher risk of exposure to corrosive materials, water or heat. Externally-powered prostheses can utilize electric, pneumatic or hybrid electrohydraulic power systems. However, because of engineering limitations of the other two, electric systems with battery power sources have become more common (Martin & Edeer, 2011).

Rehabilitation of Upper limb Amputation

Rehabilitation often starts shortly after amputation. It plays a critical role in the transition of the amputee into independent living and to return to work (Chan, 2012). There is an unusually high rejection rate of upper limb prosthesis throughout the world and it is often very difficult to predict which amputees will be successful users (Davidson, 2002). Jones and Davidson (1996) indicated that, successful outcomes are often a combination of physical, psychological and emotional factors. A multidisciplinary rehabilitation team experienced in the rehabilitation of upper limbs amputees is essential to ensure the best chance of a successful outcome (Martin & Edeer, 2011). Atkins (2002) stated that even if amputees choose to reject their prosthesis, rehabilitation should not be considered complete until they are able to achieve self-confidence and a stable independent lifestyle where social and occupational roles have been established.

According to Davidson et al., (2002), the aim of rehabilitation of people with upper limb amputation is to: develop self-esteem and confidence; regain and maintain a full range of movement in all intact joints; reduce oedema in the residual limb; manage the stump pain, phantom pain and possible neuromata; provide counseling for post-traumatic stress disorder, depression and anger management; provide the patient directed prosthetic fitting and training; assist in achieving independence in self-care, domestic and leisure activities using either a prosthesis or modified equipment; advice on the selection of modified equipment; and provide advice on vocational options and encourage return to work.

An assessment is done by the rehabilitation team shortly after amputation. The team members may consist of a physiatrist, a physiotherapist, an occupational therapist, a psychiatrist, and a prosthetist. The patient's medical history and pre-amputation activities will be reviewed. The amputee's physical condition, function, and strength of the residual limb will be assessed. With consideration of the goals of the patient, the team will discuss prosthetic options and treatment plan to allow the patient to be as independent as possible, and to prepare the amputee to return to work (Chan, 2012).

Ryan, (2012) noted that occupational therapists specializing in upper-limb prosthetic rehabilitation concentrate on developing individualized treatment plans that are specific to the level of limb loss and goals in terms of lifestyle and activities but whilst a therapist specializing in upper limb prosthetics may connect with an upper-limb patient at any point in the recovery process, it is most advantageous when he or she becomes involved during the earliest stages of medical care. According to Ryan (2012) upper-limb patients are often not given the opportunity to work with an occupational therapist in the early stages of recovery or do not understand the important role a therapist can play. The range of issues a therapist is trained to address include wound care, scar management, orthopedic disturbances, overuse of the sound limb, ergonomic adaptations, functional-activity training, patient and family education, and training to prepare patients to use a prosthetic device. Therapists also serve as patient advocates throughout the continuum of care and provide prosthetic training when patients begin wearing a prosthesis. People with upper limb amputations have a number of choices to make regarding rehabilitation and the health care team can help make those choices

(Capital Health of Nova Scotia). At the Atlantic Clinic occupational therapy care is a critical part of the rehabilitation.

Rehabilitation can occur at several times, places, and consists of many interventions. The Time, Place, Type (TPT) Framework classifies the rehabilitation processes by their timing, place, and types of service (Stineman et al. 2008).

Rehabilitation after limb amputation can be divided into nine discrete periods of evaluation and intervention (table 2). Each phase involves specific evaluation items 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 & DiGiacomo 2001). Optimally, rehabilitation of the amputee begins prior to the amputation and should be provided by a specialized treatment team as mentioned earlier. Communication among the team members, the patient, and family members is essential. The team needs information to develop a treatment plan. From the team, the patient should learn what to expect after surgery and rehabilitation. In providing this information, the treatment team will take into account the patient's physical and medical status, level of amputation, premorbid lifestyle, and cognition and will help the patient set realistic short and long-term goals. The information given by the team should include the implications of amputation and the phenomenon of phantom sensation (Esquenazi & DiGiacomo 2001).

Table 2: Phases of Amputee Rehabilitation (Esquenazi & DiGiacomo 2001)

Phase	**Hallmarks**
Preoperative	Medical and body condition assessment, patient education, surgical-level discussion, functional expectations, phantom limb discussion.
Amputation surgery/dressing	Residual-limb length determination, myoplastic closure, soft-tissue coverage, nerve handling, rigid dressing application, limb reconstruction.
Acute postsurgical	Wound healing, pain control, proximal body motion, emotional support, phantom limb.
Preprosthetic	Residual-limb shaping, shrinking, increasing muscle strength, restoring patient’s sense of control.
Prosthetic prescription/fabrication	Team consensus on prosthetic prescription.
Prosthetic training	Prosthetic management and training to increase wearing time and functional use.
Community integration	Resumption of family and community roles; regaining emotional equilibrium; developing healthy coping strategies, recreational activities.
Vocational rehabilitation	Assessment and training for vocational activities, assessment of further education needs or job modification
Follow-up	Lifelong prosthetic, functional, and medical assessment; emotional support

Emotional well-being, social concerns, residual-limb changes, and other physical issues fluctuate throughout the healing process and are addressed at all stages of treatment and rehabilitation. In the pre-prosthetic phase, rehabilitation treatment will focus on preserving strength and endurance of the residual limb, maintaining range of motion, as well as shaping and desensitizing the residual limb in preparation for the prosthesis. Once the prosthesis is fitted, the team will rehabilitate the amputee to perform functional activities using the prosthesis; the amputee will begin to learn proper donning and doffing, and operating of the prosthesis, as well as caring for the prosthesis (Chan, 2012). The rehabilitation process is aimed at allowing the amputee progressively to build tolerance, endurance, and strength in using the prosthesis to carry out functional activities. In case the amputee is planning to return to work, the team will arrange job site visits to assess the work location and occupational physical requirements. To prepare the amputee for returning to work, the team will formulate a rehabilitation plan including simulated work activities based on the identified work requirements. Workplace modifications and assistive aids are options to help the amputee in carrying out work activities (Chan, 2012).

For externally-powered prostheses, the proficiency of prosthetic control by the patient can be predicted in the early phase of rehabilitation before the prosthesis is prescribed (Smurr et al., 2008). Skills of prosthetic control can be learned during pre-prosthetic training using simulation without the amputee actually being fitted with the prosthesis (Bouwsema et al., 2010). This is important as studies have shown that early prosthetic use after amputation is important for motivation and linked to success with the prosthesis (Biddiss & Chau, 2007; Pezzin et al., 2004).

Children who require an upper limb prosthesis are usually considered ready when they begin to sit. This is the age when children begin to manipulate objects, which is an important part of development. This typically occurs between the ages of 3 and 7 months, when children develop two-handed skills (Smith, May/June 2006). Although the first prosthesis is usually passive, it can help with crawling, pushing, and pulling to sitting and standing positions. A more functional prosthesis is usually appropriate between 1 and 2 years of age, when children begin to perform more complex and coordinated activities and gain coordination. The child needs to be able to develop a link, conscious or subconscious, so that a specific muscle action results in opening or closing the terminal device. Then, the child needs to be able to coordinate placement of the terminal device and use of the terminal device with success in the final activity (Smith, May/June 2006). Generally, recommendations for early fitting of the upper limb range from ages 2 months to 2 years (Shaperman et al, 2003).

Nutrition in Upper Limb Amputation and Rehabilitation

Nutrition plays an important role during, before and after amputation. Unless amputation is performed as an emergency, one will probably go through a number of tests and procedures before the amputation takes place (NHS Choices, 2012). These are designed to assess the type of amputation suitable for the individual and anything that may affect their rehabilitation. These tests and procedures include assessing the physical condition and nutritional status of the individual (NHS Choices, 2012). Nutrition in amputation rehabilitation programs may also involve nutritional counseling to promote wound healing and health.

Nutrition in wound healing

According to Woodward et al., (2009) wound healing in simple terms, is the process of replacing injured tissue with new tissue produced by the body which demands an increased consumption of energy and particular nutrients, particularly protein and calories. Woodward et al., (2009) further indicated that a wound causes a number of changes in the body that can affect the healing process, including changes in energy, protein, carbohydrate, fat, vitamin and mineral metabolism. When the body sustains a wound, stress hormones are released in a fight-or-flight reaction and the metabolism alters in order to supply the injured area with the nutrients it needs to heal known as the catabolic phase. The body experiences an increased metabolic rate, loss of total body water, and increased collagen and cellular turnover (Woodward et al., 2009). These effects can be pronounced even with a small wound.

If the catabolic phase is prolonged and/or the body is not provided with adequate nutrient supplies, then the body can enter a protein energy malnutrition (PEM) state (Woodward et al., 2009). Factors causing prolonged catabolism include the severity of the wound and the pre-existing nutritional status of the individual. As an individual loses more lean body mass (LBM), wound healing is more likely to be delayed. With a 20% or greater loss of LBM wounds compete with muscles for nutrients. If LBM loss reaches 30% or more the body will often prioritise the rebuilding of body over wound healing with available protein (Woodward et al., 2009). There are various papers giving evidence demonstrating the essential role of nutrition in wound healing (Dickhaut et al., 1984; Eneroth 1999; Shai & Maibach 2005; Veves et al., 2006). Without adequate nutrition healing may be impaired and prolonged (Woodward et al., 2009). Improved nutritional status enables the body to heal wounds such as the accelerated wound healing seen with nutritional supplementation (Woodward et al., 2009).

Healthy eating habits are an important part of rehabilitation because of the role nutrition plays in wound healing and maintaining of healthy skin in amputee patients.

Eating habits affect weight, which in turn may alter the fit of prosthesis (Capital health of Nova Scotia).

According to the Handbook of Disabilities, (2001), when the amputation involves a limb, rather than a smaller extremity like a finger, the change in body mass can cause some problems. Individuals may have trouble with body temperature control because of the reduced skin surface. In addition, the flow of fluids in the remaining limb may be affected. The build-up of liquids in the limb (oedema) can make prosthetic devices fit improperly and contribute to skin problems. Individuals experiencing the amputation of a limb or limbs may also have difficulty with weight control. The reduced body mass means that basic nutritional needs are lower, so eating at previous levels could cause weight gain (Handbook of Disabilities, 2001). Anthropometric measurements are needed to determine the body mass in order to maintain a nutritional balance in the body.

Background of Anthropometric Measurements

Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue (National Health and Nutrition Examination Survey, 2007). The word “anthropometry” is derived from the Greek word “anthropo” meaning “human” and the Greek word “metron” meaning “measure” (Ulajaszek, 1994). The field of anthropometry encompasses a variety of human body measurements (National Health and Nutrition Examination Survey, 2007). Weight, stature (standing height), recumbent length, skinfold thicknesses, circumferences (head, waist, limb, etc.), limb lengths, and breadths (shoulder, wrist, etc.) are examples of anthropometric measures. Anthropometry is a key component of nutrition status assessment in both children and adults (Simko & Cowell, 1995).

Anthropometric data are used to evaluate health and dietary status, disease risk, and body composition changes that occur over the adult lifespan. Researchers in diverse health disciplines including cardiovascular health, gerontology, nutrition, and occupational health use anthropometric data to examine health status and health care utilization trends in adults (National Health and Nutrition Examination Survey, 2007).

Several indexes and ratios can be derived from anthropometric measurements, however, the most well-known indicator of body fatness is the body mass index (BMI) (National Health and Nutrition Examination Survey, 2007). BMI is defined as the weight in kilograms divided by the square of the height in meters (kg/m^2) (WHO, May 2012). Clinically, the International Classification of adult BMI set by World Health Organization and the National Institutes of Health can be categorized as underweight (BMI <18.5 kg/m^2), normal or desirable weight (BMI ≥ 18.5 to <25.0 kg/m^2), overweight (BMI ≥ 25.0 to <30.0 kg/m^2), and obese (BMI ≥ 30.0 kg/m^2).

According to the World Health Organization, BMI values are age independent and the same for both sexes (adults). However, BMI may not correspond to the same degree of fatness in different ethnic groups, partly due to different body proportions (percentage of body fat and body fat distribution differ).

While BMI obtained through measurement of standing height and body weight is a common index of nutritional health used in the general population, there are considerable complexities involved in obtaining these measures in the amputee population. Only a small number of studies have attempted to establish methods for assessing BMI in the amputee population such as (Mozumdar and Roy, 2004;

Tzamaloukas et al., 1994; Tzamaloukas et al., 1996). These studies focused on lower limb amputee populations, clearly demonstrate that using actual post-amputation weight significantly underestimates BMI and consequently leads to inaccurate assessment of nutritional health (Preedy, 2012; Bannerman et al., 2012).

To overcome this issue, it is suggested that an adjusted weight would be more appropriate for use in the standard BMI equation (Preedy, 2012; Bannerman et al., 2012). Bannerman et al., (2012) indicated that the methods employed in these studies were based on mathematical determination of body weight based on pre –and post amputation weights and the proportion of weight attributable to the amputated body segment, which could then be used in the standard BMI equation. Comparisons could then be made to the standard BMI reference ranges to determine BMI status in the amputee.

Bannerman et al., (2012) noted that although the formulae were well developed, the method would be difficult to implement in the clinical setting. Also no evidence was provided to support the use of BMI in these health settings over the use of monitoring changes in body weight in terms of subsequent health outcomes. Although amputees may need up to 25 percent more calories than normal immediately following their surgery, their caloric needs will eventually be decreased, as well as their ideal body weight (Woods, 2011).

Body weight is a good indicator of a person's size and is widely used in assessments (Escott-Stump, 2008). Body mass index (BMI) values in individuals with limb amputation are less than those in healthy control population without limb amputation because the lost weight of the limbs is not considered in calculating BMI

(Modan et al., 1998). Mozumdar and Roy (2004) indicated that estimated body weight is more reliable than observed weight in patients with limb amputation.

Clinic Profile

The Atlantic Clinic for Upper Limb Prosthetics is a prosthetic fitting centre for children and adults with an upper limb deficiency. The clinic has patient visit records going back to 1981. It is run jointly by the Institute of Biomedical Engineering (IBME) at the University of New Brunswick and the Stan Cassidy Centre for Rehabilitation (SCCR), the province of New Brunswick's tertiary rehabilitation centre (Craig, 2011). The clinic's statistics show that the majority (83%) of the clients are adults with 17% of children under the age of 18 years. From the children population, 73% of the clients seen were congenital, of which a further 63% were females and 37% males.

The Atlantic Clinic for Upper Limb Prosthetics enrolls two to three children with an upper limb deficiency annually. In Canada, between 25 and 50 children are born each year with a congenital upper limb deficiency requiring prosthetic treatment (McDonnell, et al., 1988; Craig, 2011).The Atlantic Clinic for Upper Limb Prosthetics specializes in fitting myoelectric prostheses; however, other types of fittings are also offered such as cosmetic restorations, passive prostheses, body powered prostheses, recreational adaptations, or specially designed custom prosthetic devices. The type of fitting is determined based on the desire of the client and family, the client's lifestyle and vocational interests as well as funding considerations.

Clients of the clinic predominantly come from Atlantic Canada, however, some clients travel over 5,000 km to receive prostheses at the clinic. With regards to funding, the Institute of Biomedical Engineering is not in a position to provide funding, however, the staff are able to assist clients in seeking financial support. Many provinces in Canada provide partial funding for prosthetic rehabilitation. Most people who have been to the clinic have received funding from the following agencies: CHAMP Program of the War

Amps, workplace insurance; private health insurance, accident insurance benefits and community service groups.

Methodology

Research Design and Sampling Procedure

This research study involves the use of secondary data from the Atlantic Canada Upper Limb Prosthetic Clinic database. The clinic data comprises information such as patient visits, demographics (age, gender), financials per visit, reasons for each visit, type of amputee loss (congenital / acquired), level of limb loss, type of prosthetic use over time, distance travelled by clients to clinic, type of coverage etc. The clinic also has anthropometric data (weight, height) for a subset of working age patients. The data are in a database (Microsoft Access) and related to each patient are a table of demographic data and a separate entry for each visit to the clinic. The clinic database has a total of 212 patients with some visit records going back to 1981 when the clinic opened.

This research used a quantitative method of approach and the design for the study is retrospective since it involves the use of data going back to 1981 and cross sequential in nature (mostly cross sectional but longitudinal by visit). The sampling procedure used in this study is purposive. This type of sampling seeks to select sections of the research population which in the researcher's judgment will provide the most useful information for the study. Ideally, it gives a sample that is perfectly representative of the target population.

Preparing and Analyzing Clinic Data

Prior to the start of this study, ethics approval was obtained from the UNB ethics review board. In preparing the clinic data for analysis, all potential data of interest were first and foremost transferred from Microsoft Access to Microsoft Excel and then to SPSS or Minitab but the original data files were not altered. The next step involves addressing any missing data by identifying/labeling missing values in the software program and selecting a method for handling missing data. Some variables were recoded for use in SPSS (example is gender, type of loss, level of loss and side of loss). The variables exist describing the following groups; gender (0= "Male 1= "Female"), type of loss (0= "Congenital" 1= Acquired), side of loss (0= "Left" 1= "Right" 2= "Both") and level of loss (1= "Partial hand" 2= "Wrist disarticulation" 3= "Transradial" 4= "Elbow disarticulation" 5= "Transhumeral" 6= "Shoulder disarticulation" 7= "Forequarter" 8= "Other" 9= "Transradial/Partial hand" 10= "Transradial/Transhumeral"). The final step involves the creation of new variables (weight, height, body weight status).

Based on the guided research questions, the appropriate statistical analysis and software package were identified and selected. This implemented analysis and determined adequacy of the sample size. In this research SPSS software was used in analyzing statistical data, Minitab software was used in plotting graphs and the results interpreted whilst protecting confidentiality. The clinic data were analyzed in two parts; the entire patient group since 1981, and a subset of working age patients.

Statistical Analysis

Statistical analyses reflecting the sampling design were used. This research placed a strong emphasis on the most common descriptive analysis methods; means, cross- tabulation, correlation, ranking, unpaired t-test and one-way analysis of variance. Simple linear regression was also included as an example of predictive analysis.

The descriptive analysis of the clinic data involved the measurement of summary statistics of observations and distributions with which different values of the variable occurred. Summary statistics (mean and variance or the square root of a variance, the standard deviation) were employed to describe the essential characteristics of the distribution. Other measures included the median, percentiles, mean absolute deviation, frequencies, etc. Summary statistics conveyed essential information about the data set and it was also used to identify the more obvious errors existing in the data set. These were identified for subsequent correction and those values were excluded from the analysis.

Visual presentations of data (tables and graphics) were employed and this is an extremely powerful tool for conveying the information of a data set when properly used. The box plot was used to display data for analysis (clients' age, distance from Fredericton, etc.). The visual presentations employed helped to organize and present data, to detect errors, inconsistencies and outliers of the data set. Although the box plot presented information from the data set in a more compressed fashion, it was very useful in depicting the general structure of the data set and detecting outliers. It plotted the median, the 25th percentile, the 75th percentile, the outliers and extreme values as shown in figures 19 to 23. The length of the box shows the spread or variability of the observations.

One of the primary objectives of a statistical analysis is to use data from a sample to make inferences about the population from which the sample was drawn. Statistical inferences were basically performed for two purposes that is test of hypotheses and estimation. An unpaired *t*-test was used to compare the mean age in female and male clients. Fisher's exact test was used to test for gender differences in the number of amputations. A one-way ANOVA analysis was also used to compare the various levels of upper limb amputations in the clinic data and regression analysis for the various variables.

Anthropometric Data

Anthropometry is an important tool in the assessment of the health and nutritional status of a population. Purposive sampling is applied in this study for a subset of 34 working age patients to estimate the Body Mass Index (BMI) from the anthropometric data (weight, height). These data were collected as part of a study of risk factors for Repetitive Strain Injury and were already linked to the clinic data. The sample size is intended to reflect at least 10% of the total clinic population. Observations were restricted to this subgroup and conclusions from the data obtained were generalized to the total population. To calculate the BMI of an acquired amputee, the true body weight (TBW) of the amputee that is the body weight before amputation was needed. In order to do this, the corresponding average % total weight of the amputated limb from Table 3 was used. For persons with transhumeral level of loss in this study 0.7% (hand) is subtracted from 5% (entire arm) to reflect the mass of a typical transhumeral residual limb and the value obtained (4.3%) is used as the % weight of the amputated limb. This is to prevent over estimation of weight in patients with transhumeral loss since the amputation occurs in the upper arm from the elbow to the shoulder and not the entire arm in most cases. After obtaining the estimated weight of the amputated limb, one can then proceed to calculate the true body weight of the amputee. The table below illustrates values for adjustment of desirable body weight for Amputees.

Table 3: Adjustment of Ideal Body weight for Amputees (Mahan et al., 2012)

Body Segment	**Average % of Total Weight**
Lower arm and hand	2.3
Trunk without extremities	50.0
Entire arm	5.0
Hand	0.7
Entire lower leg	16.0
Below knee including foot	5.9
Foot	1.5

The percentages listed in table 3 are estimates because body proportions vary in individuals. The use of these percentages provides an approximation of desirable body weight, which is more accurate than a comparison with the standards for normal adults. Ideal body weight (IBW) must be adjusted downward to compensate for missing limbs or paralysis. It is estimated that 5% to 10% should be subtracted from IBW for a paraplegic and from 10% to 15% subtracted for a tetraplegic (quadriplegic) (Mahan et al., 2012).

The equation for true body weight is given as:

$$\frac{\text{Present body weight}}{100 - \text{ Average \% of the amputated limb}} \text{ x } 100$$

Example 1:

For a transhumeral amputee in this study with an assumed weight 86.2kg and height of 1.8m, true body weight will be =

$$\frac{86.2}{100 - (5 - 0.7)} \text{ x } 100$$

= 90.1kg

To further calculate the Body Mass Index (BMI) of the amputee clients, the results obtained for the true body weight were used in the BMI formula:

$$BMI = \frac{\text{True Body Weight(kg)}}{\text{Height(m}^2)} = 703 \text{ x } \frac{\text{True Body Weight (lb)}}{\text{Height(in)}^2}$$

The equation above is given by Wolfus (2012).

Example 2:

$$\text{BMI} = \frac{90.1}{(1.8)^2}$$

$$\text{BMI} = 26.9\text{kg/m}^2$$

The International Classification of adult BMI set by World Health Organization and the National Institutes of Health was used to categorized the values obtained in this study as underweight (BMI <18.5 kg/m^2), normal or desirable weight (BMI ≥ 18.5 to <25.0 kg/m^2), overweight (BMI ≥ 25.0 to <30.0 kg/m^2), and obese (BMI ≥ 30.0 kg/m^2). Once the BMI's were calculated, the body weight status was established and coded (1= "Underweight" 2= "Normal" 3= "Overweight" 4= "Obese"). In addition to other variables (total number of visits for fit issue, age, time lapse (mth) before prosthesis fitting, distance travelled from Fredericton, average number of days spent per visit), descriptive and inferential statistics were performed and the results interpreted.

A nutritional package in the form of brochure providing information on limb loss and nutrition was developed as part of this project and is included in the appendix. It contains the following information; Atlantic Clinic contact details; the categories of upper limb amputation; BMI; adjustment of body weight for amputees, formula for adjusting body weight; BMI chart; health risk classification according to BMI; and how to reduce risk for obesity related diseases.

Advantages and Limitations

The biggest advantage of using this clinic data was that it saved the researcher time, money, energy, and other resources in this phase of research. Since the data were already collected and usually cleaned and stored in electronic format, the researcher spent most of the time analyzing the data instead of getting the data ready for analysis. Also another major advantage of using this clinic data is that the data collection process were guided by experts and professionals which may not be available to the individual researcher and therefore makes it ideal for use in this masters' thesis.

A major limitation of using this clinic data was that it may not have answered the researcher's specific research questions or contain specific information that the researcher would like to have such as service hours used to build prosthesis. This may limit the analysis or alter the original questions sought out to answer. A related problem was that the variables were defined or categorized differently than the researcher would have chosen. Also another limitation was the small sample size for the subset of working age group and lack of data on body weight before amputation in acquired clients. Since the researcher did not collect the data, the researcher has no control over what is contained in the data set.

Results

General Overview of Atlantic Clinic

The clinic had a total client population of 212 since inception in 1981 as indicated in table 4 below. Out of the 212 clients, 135 were males representing 63.7% of the total population and the remaining 77 were females representing 36.3%. Within the male population 17 were children under the age of 18 years whilst amongst the females 20 clients were under the age of 18 years. Overall, the clinic had a population of 17% children and 83% adults (56% male and 27% females). However, the clinic has an active client population of 138 and these are clients with visit records within the last 10 years from 2003 to 2013. Amongst the active clients, 50 were females representing 36.2% whereas the remaining 88 were males representing 63.8%.

Table 4a: Total Clients Gender Frequency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	135	63.7	63.7	63.7
	Female	77	36.3	36.3	100.0
	Total	212	100.0	100.0	

4b. Active Clients Gender Frequency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	88	63.8	63.8	63.8
	Female	50	36.2	36.2	100.0
	Total	138	100.0	100.0	

Figure 4: Pie Chart Representation of Gender

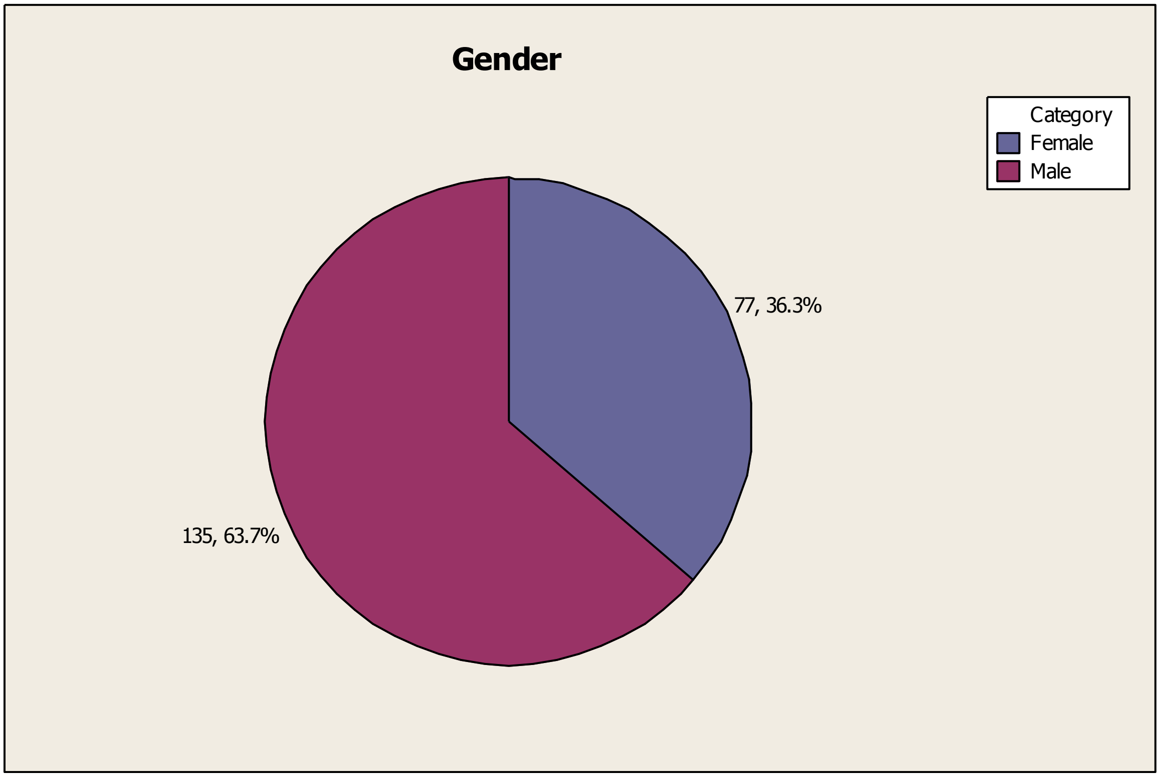


Table 5a: Total Clients Type of Loss Frequency

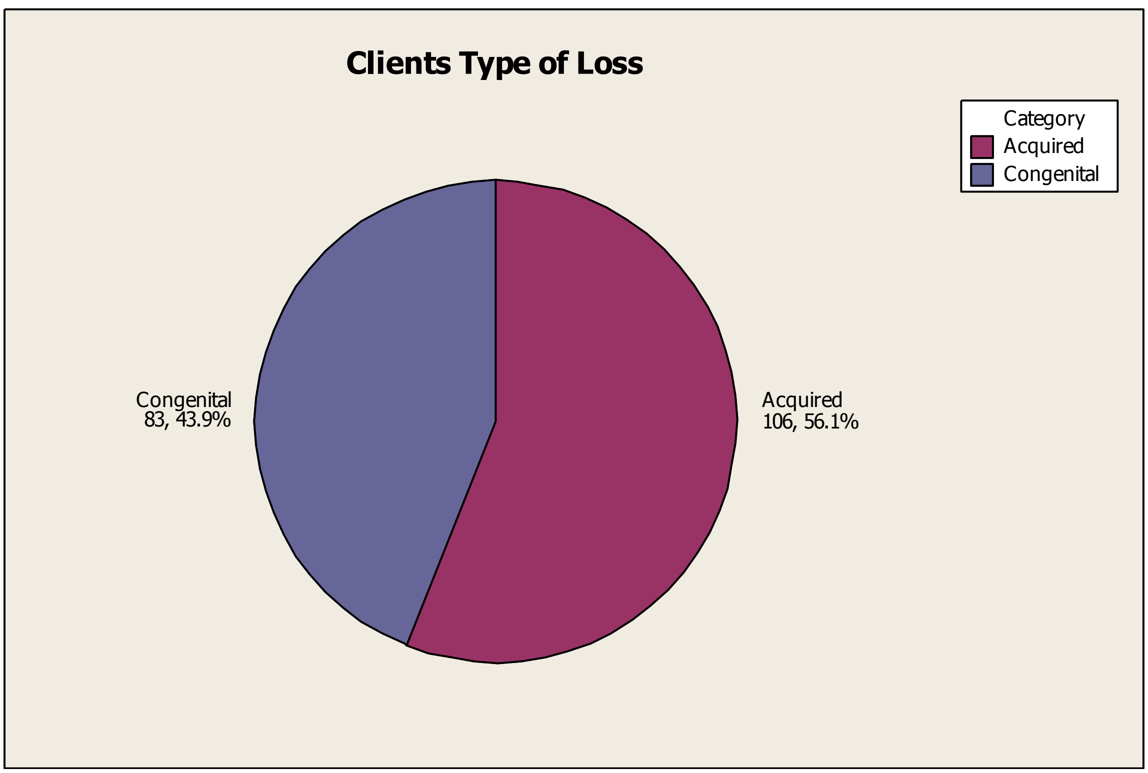
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Congenital	83	39.2	43.9	43.9
	Acquired	106	50.0	56.1	100.0
	Total	189	89.2	100.0	
Missing	System	23	10.8		
Total		212	100.0		

The type of loss was categorized as either congenital or acquired. Table 5 and figure 5 gives a breakdown of the frequencies in the type of loss. From the clinic total population of 212 clients, a total of 83 clients were congenital and 106 clients were acquired. There were missing records for 23 clients in the database. Hence in terms of valid percentage, 43.9% of the total client population were congenital and 56.1% were acquired.

5b. Active Clients Type of Loss Frequency

		Frequency	Percent	Valid Percent	Cumulative Percent
	Congenital	57	41.3	46.7	46.7
Valid	Acquired	65	47.1	53.3	100.0
	Total	122	88.4	100.0	
Missing	System	16	11.6		
Total		138	100.0		

Figure 5: Pie Chart Representation of Total Clients Type of Loss



Within the active clients population a total of 57 clients were congenital and 65 clients were acquired. There were missing records for 16 clients in the database. Hence in terms of valid percentage, 46.7% of the active client population were congenital and 53.3% were acquired.

Table 6a: Cross Tabulation of Total Clients Gender with Type of Loss

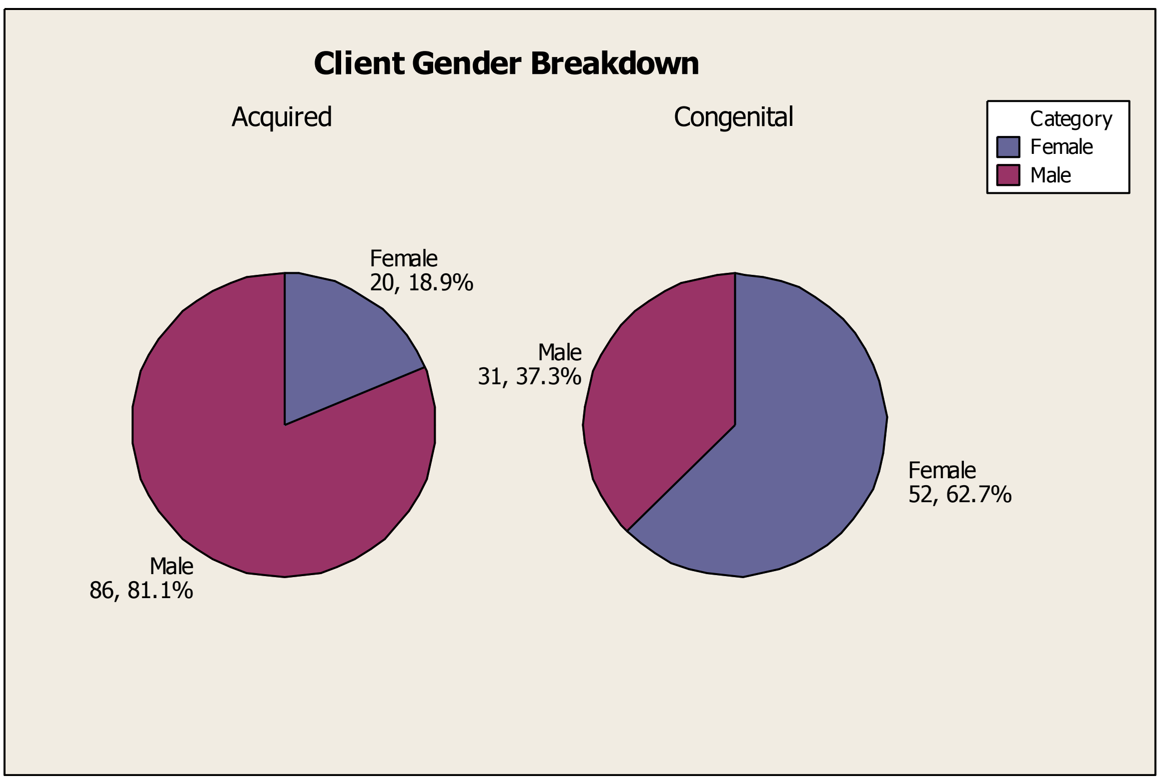
			Type of Loss		Total
			Congenital	Acquired	
Gender	Male	Count	31	86	117
		% within Gender	26.5%	73.5%	100.0%
		% within Type of Loss	37.3%	81.1%	61.9%
	Female	Count	52	20	72
		% within Gender	72.2%	27.8%	100.0%
		% within Type of Loss	62.7%	18.9%	38.1%
Total		Count	83	106	189
		% within Gender	43.9%	56.1%	100.0%
		% within Type of Loss	100.0%	100.0%	100.0%

From table 6 and figure 6, within the total client congenital population 52 clients were females representing 62.7% and 37.3% were males representing 31 clients. In the acquired population 20 clients were females representing 18.9% whilst 86 clients were males representing 81.1%. In all, the cross tabulation accounted for 189 total clients with complete records.

6b: Cross Tabulation of Active Clients Gender with Type of Loss

			Type of Loss		Total
			Congenital	Acquired	
Gender	Male	Count	22	53	75
		% within Gender	29.3%	70.7%	100.0%
		% within Type of Loss	38.6%	81.5%	61.5%
	Female	Count	35	12	47
		% within Gender	74.5%	25.5%	100.0%
		% within Type of Loss	61.4%	18.5%	38.5%
Total		Count	57	65	122
		% within Gender	46.7%	53.3%	100.0%
		% within Type of Loss	100.0%	100.0%	100.0%

Figure 6: Pie Chart of Total Clients Gender Breakdown with Type of Loss



Within the active client congenital population, 35 clients were females representing 61.4% and 38.6% were males representing 22 clients. In the acquired population, 12 clients were females representing 18.5% whilst 53 clients were males representing 81.5%. The cross tabulation accounted for 122 active clients with complete records.

Table 7a: Frequency Table of Total Clients Side of Loss

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Left	101	47.6	52.9	52.9
	Right	79	37.3	41.4	94.2
	Both	11	5.2	5.8	100.0
	Total	191	90.1	100.0	
Missing	System	21	9.9		
Total		212	100.0		

The side with loss was categorized as left, right or both as seen in table 7. Out of a total of 212 clients, there were 21 clients with missing records. In all 101 clients had their limb loss on the left representing 52.9% of the valid cases whilst 79 clients were right sided limb loss representing 41.4% of the valid cases. However, 11 clients had both left and right limb loss representing 5.8% of the valid cases. Figure 7 below gives the graphical representation in the frequencies of the side with loss.

7b: Frequency Table of Active Clients Side of Loss

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Left	68	49.3	55.7	55.7
	Right	48	34.8	39.3	95.1
	Both	6	4.3	4.9	100.0
	Total	122	88.4	100.0	
Missing	System	16	11.6		
Total		138	100.0		

Within the 138 active clients, 68 clients had their limb loss on the left representing 55.7% of the valid cases whilst 48 clients were right sided limb loss representing 39.3% of the valid cases. There were 6 clients with both left and right limb loss representing 4.9% of the valid cases and 16 clients with missing records.

Figure 7: Pie Chart Representation of Total Clients Side with Loss

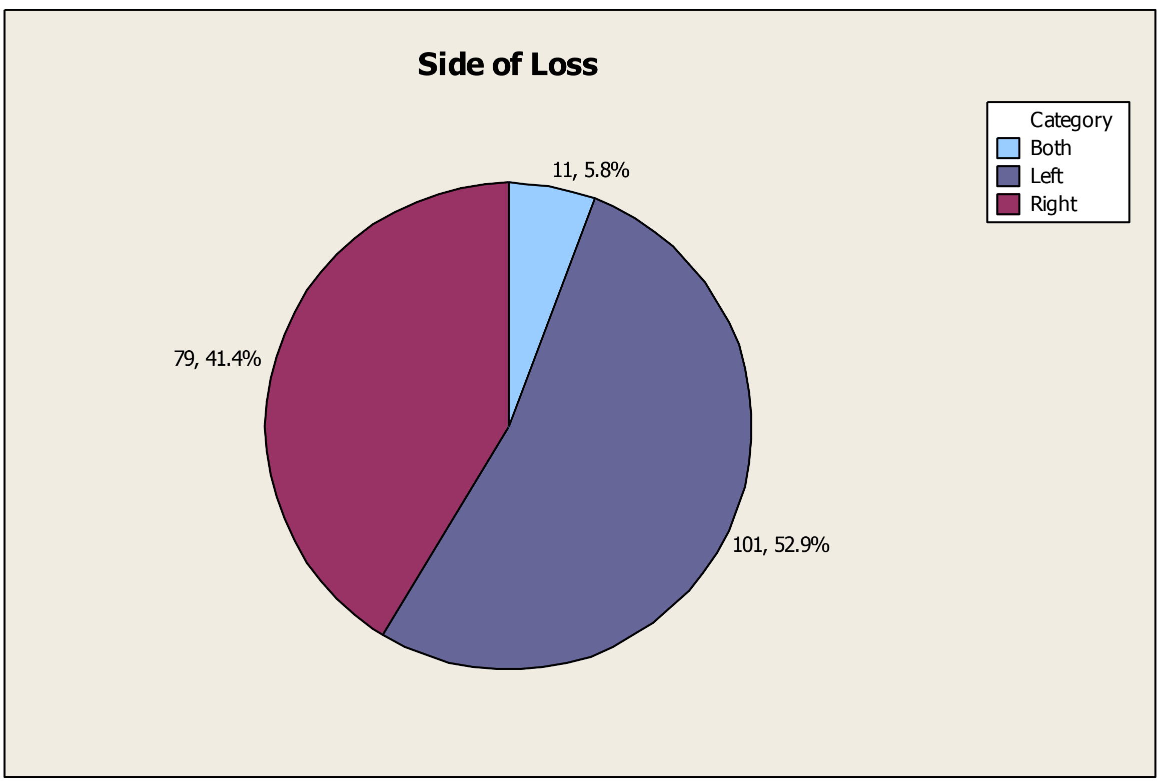


Table 8a: Cross Tabulation of Total Clients Side of Loss with Type of Loss

			Type of Loss		Total
			Congenital	Acquired	
Side with Loss	Left	Count	47	47	94
		% within Side with Loss	50.0%	50.0%	100.0%
		% within Type of Loss	56.6%	49.0%	52.5%
	Right	Count	30	46	76
		% within Side with Loss	39.5%	60.5%	100.0%
		% within Type of Loss	36.1%	47.9%	42.5%
	Both	Count	6	3	9
		% within Side with Loss	66.7%	33.3%	100.0%
		% within Type of Loss	7.2%	3.1%	5.0%
Total		Count	83	96	179
		% within Side with Loss	46.4%	53.6%	100.0%
		% within Type of Loss	100.0%	100.0%	100.0%

From table 8a above, within the total congenital population 30 clients had their limb loss on the right side representing 36.1% and 56.6% were left sided limb loss representing 47 clients. However, 7.2% had limb loss on both sides representing 6 clients. In the total acquired population 46 clients had their limb loss on the right side representing 47.9% and 47 clients were left sided limb loss representing 49%. Also 3.1% had limb loss on both sides representing 3 clients. The entire cross tabulation accounted for 179 total clients with known records. Figure 8 below gives the graphical representation of the total client frequencies.

8b: Cross Tabulation of Active Clients Side of Loss with Type of Loss

			Type of Loss		Total
			Congenital	Acquired	
Side	Left	Count	35	28	63
		% within Side	55.6%	44.4%	100.0%
		% within Type of Loss	61.4%	49.1%	55.3%
	Right	Count	20	27	47
		% within Side	42.6%	57.4%	100.0%
		% within Type of Loss	35.1%	47.4%	41.2%
	Both	Count	2	2	4
		% within Side	50.0%	50.0%	100.0%
		% within Type of Loss	3.5%	3.5%	3.5%
Total		Count	57	57	114
		% within Side	50.0%	50.0%	100.0%
		% within Type of Loss	100.0%	100.0%	100.0%

From table 8b above, within the active client congenital population 20 clients had their limb loss on the right side representing 35.1% and 61.4% were left sided limb loss representing 35 clients. However, 2 active clients had limb loss on both sides representing 3.5%. In the acquired active client population 27 clients had their limb loss on the right side representing 47.4% and 28 clients were left sided limb loss representing 49.1%. Also 3.5% had limb loss on both sides representing 2 clients. The cross tabulation accounted for 114 active clients with known records.

Figure 8a: Pie Chart Breakdown of Total Clients Side of Loss with Type of Loss

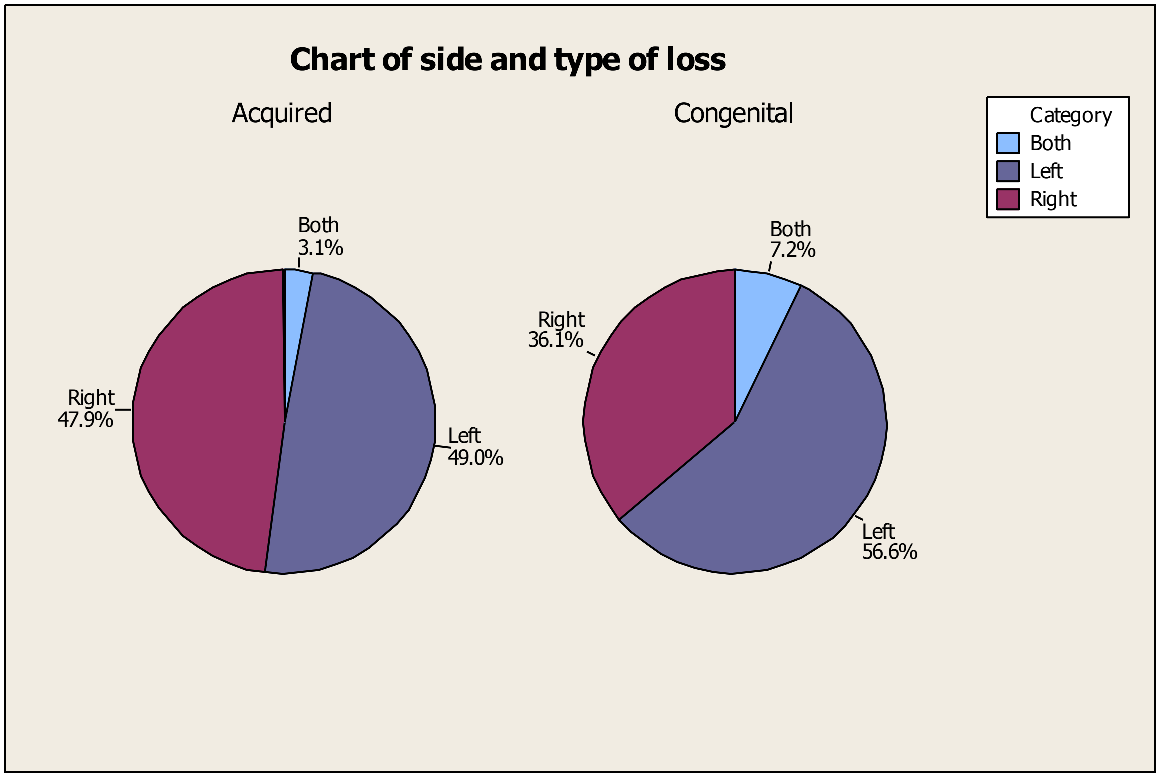
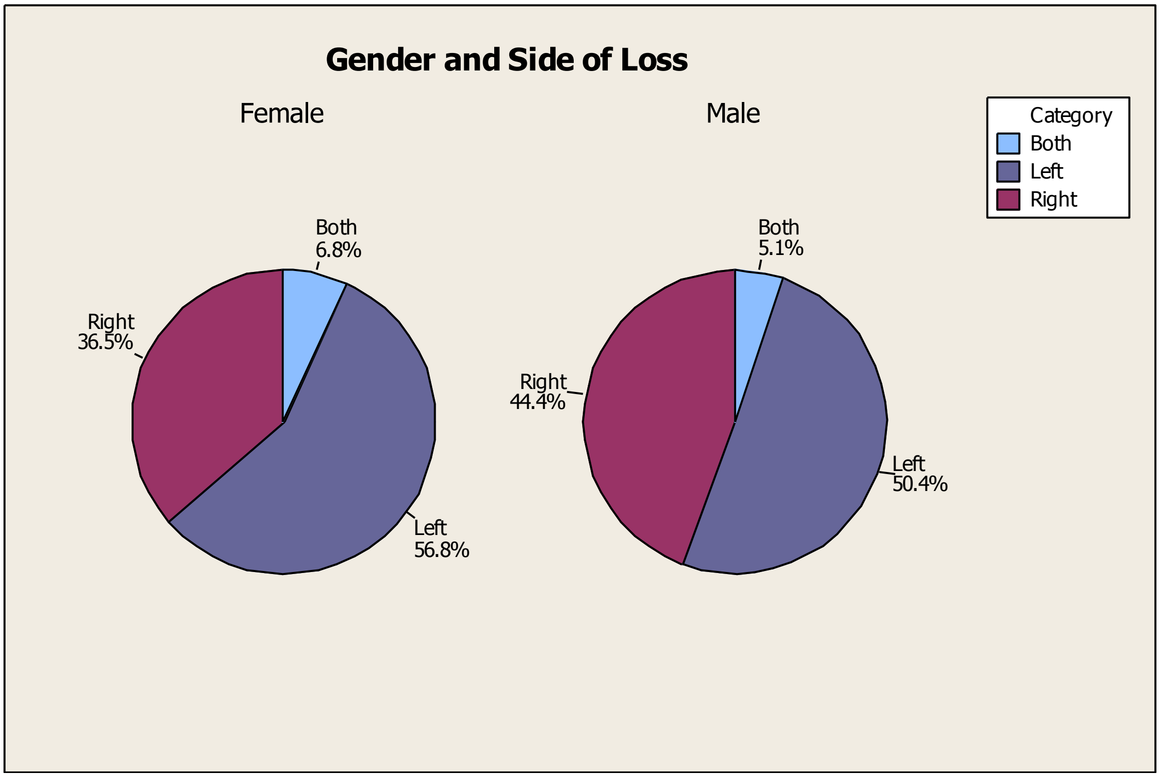


Table 8c: Cross Tabulation of Side of Loss with Gender

			Gender		Total
			Male	Female	
Side with Loss	Left	Count	59	42	101
		% within Gender	50.4%	56.8%	52.9%
	Right	Count	52	27	79
		% within Gender	44.4%	36.5%	41.4%
	Both	Count	6	5	11
		% within Gender	5.1%	6.8%	5.8%
Total		Count	117	74	191
		% within Gender	100.0%	100.0%	100.0%

Figure 8b: Pie Chart Breakdown of Total Clients Side of Loss with Gender



With regards to the level of limb loss or amputation, there were missing records of 31 out the 212 total clients as represented in table 9 below. Clients with transradial level of loss or amputations were most common. In all there were 81 transradial clients representing 44.8% of the valid cases. The clinic accounted for 39 clients with partial hand limb loss or amputations indicating a total of 21.5% valid cases. Clients with transhumeral level of limb loss or amputations were 35 in total. This represents a total of 19.3% of valid cases. There were 10 clients with wrist disarticulation, representing 5.6% whilst 6 clients were shoulder disarticulation representing 3.3% of valid cases. Forequarter limb loss or amputations were only 2 representing 1.1% whereas 4 clients were other level of limb loss or amputation which represents 2.2% of valid cases. There were 2 clients with elbow disarticulation representing 1.1% of valid cases. There were 2 clients with bilateral (partial hand/transradial and transradial/transhumaral) limb loss or amputations, each representing 0.6% of valid cases. Figure 9 below gives a graphical representation of total client frequency in the levels of limb loss or amputation.

Table 9a: Frequency Table of Total Clients Level of Limb Loss

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Partial Hand	39	18.4	21.5	21.5
	Wrist Disarticulation	10	4.7	5.5	27.1
	Transradial	81	38.2	44.8	71.8
	Elbow Disarticulation	2	.9	1.1	72.9
	Transhumeral	35	16.5	19.3	92.3
	Shoulder Disarticulation	6	2.8	3.3	95.6
	Fore Quarter	2	.9	1.1	96.7
	Other	4	1.9	2.2	98.9
	Partial hand/Transradial	1	.5	.6	99.4
	Transradial/Transhumeral	1	.5	.6	100.0
	Total	181	85.4	100.0	
Missing	System	31	14.6		
Total		212	100.0		

Within the active client populations in table 9b, there were 61 transradial clients representing 50% of the valid cases. The clinic accounted for 22 active clients with partial hand limb loss or amputations indicating a total of 18% valid cases. Clients with transhumeral level of limb loss or amputations were 23 in total. This represents a total of 18.9% of valid cases. There were 6 clients with wrist disarticulation, representing 4.9% whilst 4 clients were shoulder disarticulation representing 3.3% of valid cases.

9b: Frequency Table of Active Clients Level of Limb Loss

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Partial Hand	22	15.9	18.0	18.0
	Wrist Disarticulation	6	4.3	4.9	23.0
	Transradial	61	44.2	50.0	73.0
	Elbow Disarticulation	1	.7	.8	73.8
	Transhumeral	23	16.7	18.9	92.6
	Shoulder Disarticulation	4	2.9	3.3	95.9
	Forequarter	1	.7	.8	96.7
	Other	3	2.2	2.5	99.2
	Transradial/Partial hand	1	.7	.8	100.0
	Total	122	88.4	100.0	
Missing	System	16	11.6		
Total		138	100.0		

There was 1 active client with elbow disarticulation representing 0.8% of valid cases and the same for forequarter limb loss or amputation. However, 3 clients were other level of limb loss or amputation which represents 2.5% of valid cases with 1 client being bilateral (partial hand/transradial) representing 0.8% of valid cases. In all there were missing records of 16 out the 138 active clients as represented in table 9b above.

Figure 9: Pie Chart Representation on Total Clients Levels of Limb loss

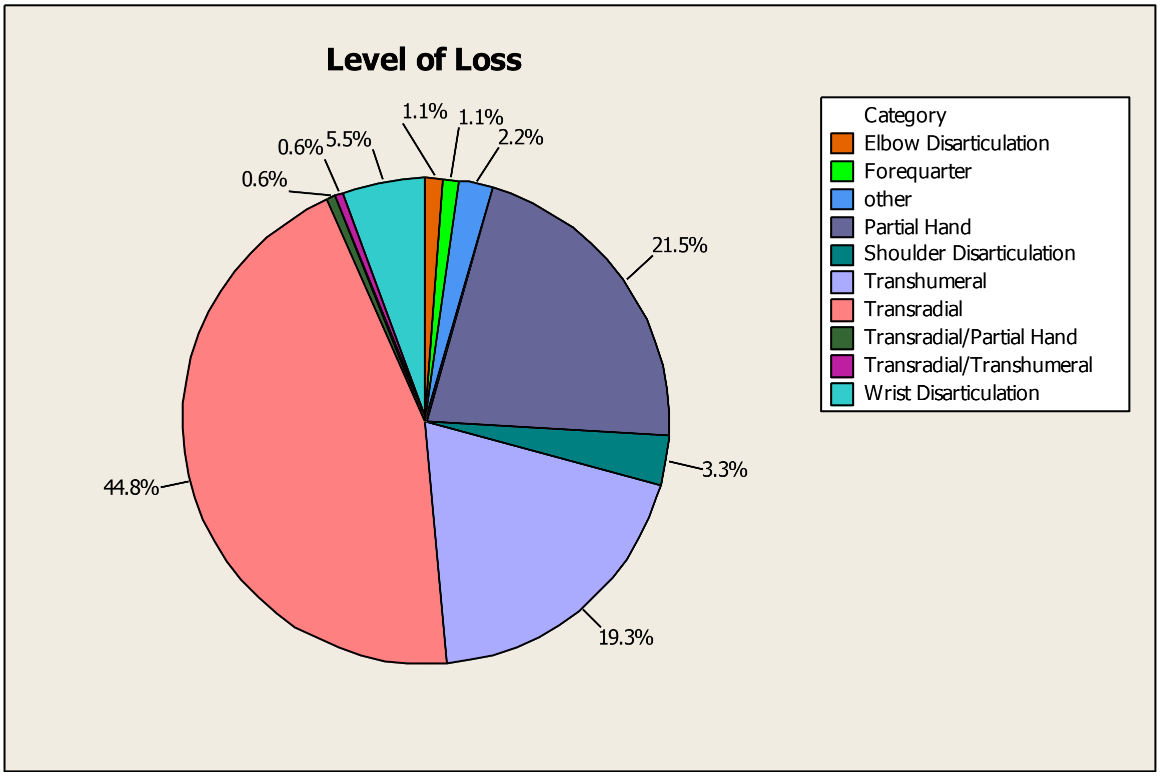
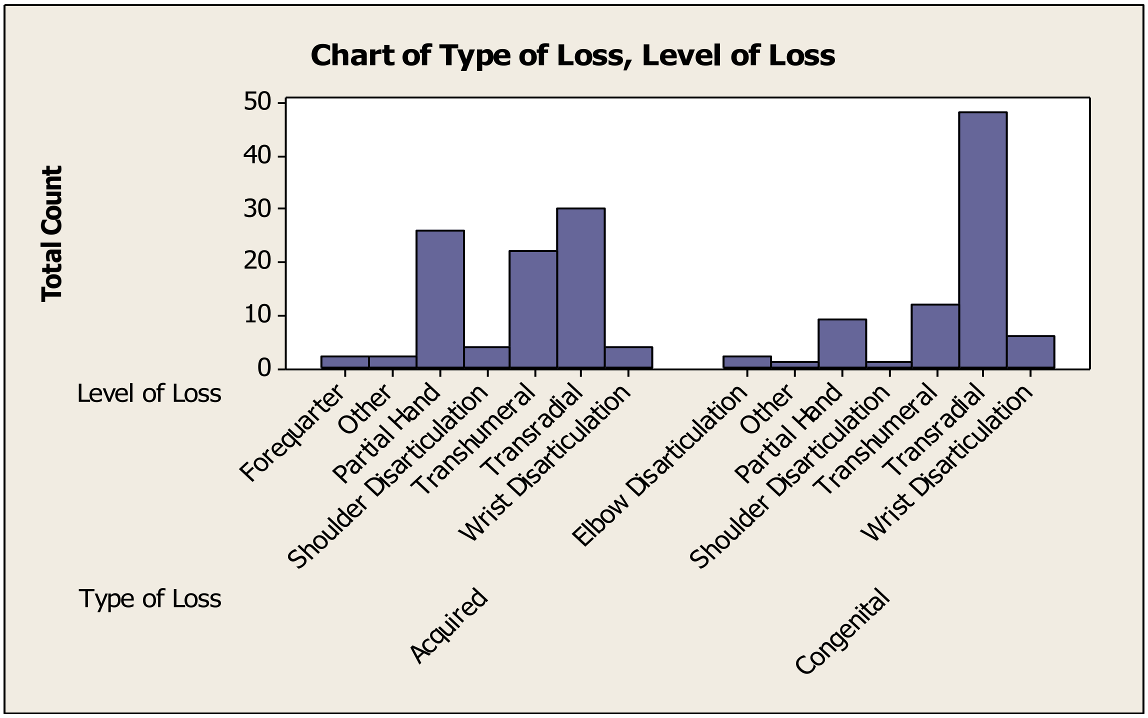


Table 10: Total Clients Cross Tabulation on Level of Loss and Type of Loss

		Type of Loss		Total
		Congenital	Acquired	
Level of Loss	Partial Hand	9	26	35
	Wrist Disarticulation	6	4	10
	Transradial	47	31	78
	Elbow Disarticulation	2	0	2
	Transhumeral	12	22	34
	Shoulder Disarticulation	1	4	5
	Fore Quarter	0	2	2
	Other	1	2	3
	Partial hand/Transradial	0	1	1
	Transradial/Transhumeral	0	1	1
Total		78	93	171

Figure 10: Comparison Graph for Total Clients (excluding bilateral clients) on Level of Loss and Type of Loss



From the cross tabulation, it is seen that in both congenital and acquired clients transradial was most common, although it was higher in congenital clients a total of 47 compared to 31 acquired clients. Also within the acquired group, partial hand was the second highest with a total of 26 clients whilst within the congenital clients only 9 were partial hand. A total of 6 congenital clients were wrist disarticulation compared to 4 clients in the acquired. There were 12 congenital clients who were transhumeral compared to 22 in the acquired. Also 4 acquired clients and 1 congenital client had shoulder disarticulation level of loss. There were 2 congenital clients with elbow disarticulation and also 2 acquired clients with forequarter level of loss. Also 2 of the acquired clients and 1 congenital client had other level of loss.

Mean Age in Total Clients (male and female)

Unpaired t-test was used to determine significant difference between the mean age in male and female clients.

Table 11a: Independent samples to compare mean age in male and female clients.

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Age	Male	120	39.80	20.595	1.880
	Female	75	29.53	16.933	1.955

Table 11b: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Age	Equal variances assumed	5.647	.018	3.619	193	.000	10.267	2.837	4.671	15.862
	Equal variances not assumed			3.785	178.959	.000	10.267	2.713	4.914	15.619

The t-test table shows that the Levene's test had an F-statistics of 5.647 with a significance value of 0.018. Since 0.018 < 0.05, the variables had a statistically different variance distributions. Equal variances not assumed indicate that the t-statistics value was 3.785 with 178.959 degrees of freedom. The 2-tailed significance value was 0.000. The difference between age means was 10.3 and the standard error of the difference was 2.7. The 95% confidence interval of the difference ranged from 4.9 to 15.6. Hence, because 0.000 < 0.05, the mean age was statistically significantly higher for males by 10.3 years.

Gender Differences in the Types of Amputations

Fisher's exact test was used to test for gender differences in the number of people with amputations in the clinic. From the chi-square table the expected count is less than 5 for 0.0% and both 2-sided and 1-sided exact significance have the same value of 0.000. Since 0.000 < 0.05 it represents a statistically significant relationship between type of loss and gender. There were 37.3% congenital males compared to 81.1% acquired males. Also within the females 62.7% were congenital compare to 18.9% acquired. Hence the difference is large enough and highly statistically significant.

Table 12a: Fisher's exact test for gender differences in the types of amputations

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Gender * Type of Loss	189	89.2%	23	10.8%	212	100.0%

12b: Gender and Type of Loss Crosstabulation

			Type of Loss		Total
			Congenital	Acquired	
Gender	Male	Count	31	86	117
		% within Gender	26.5%	73.5%	100.0%
		% within Type of Loss	37.3%	81.1%	61.9%
	Female	Count	52	20	72
		% within Gender	72.2%	27.8%	100.0%
		% within Type of Loss	62.7%	18.9%	38.1%
Total		Count	83	106	189
		% within Gender	43.9%	56.1%	100.0%
		% within Type of Loss	100.0%	100.0%	100.0%

12c: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	37.838[a]	1	.000		
Continuity Correction[b]	36.005	1	.000		
Likelihood Ratio	38.829	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	37.638	1	.000		
N of Valid Cases	189				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 31.62.
b. Computed only for a 2x2 table

One way ANOVA on Level of Loss in Comparison to Gender

A one way ANOVA was performed with level of loss as the dependent variable and gender as the independent variable. Level of loss was coded as (1= “Partial hand” 2= “Wrist disarticulation” 3= “Transradial” 4= “Elbow disarticulation” 5= “Transhumeral” 6= “Shoulder disarticulation” 7= “Forequarter” 8= “Other”).

Table 13a: One way ANOVA descriptive of Level of Loss in Comparison to Gender

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Male	112	3.23	1.968	.186	2.86	3.60	1	10
Female	69	3.25	1.429	.172	2.90	3.59	1	8
Total	181	3.24	1.778	.132	2.98	3.50	1	10

Table 13b: Test of Homogeneity of Variance

Levene Statistic	df1	df2	Sig.
9.131	1	179	.003

The table ‘Test of Homogeneity of Variances’ test for equality of variances. It tests the condition that the variances of both samples are equal, as indicated by the Levene Statistic. The *p*-value of Levene test indicates difference of variances in the population and this is significant at *P*-value 0.003.

In the ANOVA table, the variation (*Sum Of Squares*), the degrees of freedom (*df*), and the variance (*Mean Square*) is given for the within and the between groups, as well as the F value (*F*) and the significance of the F (*Sig.*). *Sig.* indicates whether the null hypothesis (the population means are all equal) has to be rejected or not. In this test there is not much difference between the two Mean Squares (0.009 and 3.178), resulting in a not significant difference ($F = 0.003$; *Sig.* = 0.958). This means that null hypothesis at the 5% or 1% level cannot be rejected. Thus, the mean level of loss in male and female is the same, since they both fall within 3, representing transradial. The “Robust

Tests of Equality of Means" confirms that indeed the means are the same (*F* = 0.003; *Sig*. = 0.955).

Table 13c: ANOVA Table

Level of Loss	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.009	1	.009	.003	.958
Within Groups	568.776	179	3.178		
Total	568.785	180			

13d: Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	.003	1	174.132	.955
Brown-Forsythe	.003	1	174.132	.955

a. Asymptotically F distributed.

One way ANOVA on Level of Loss in Comparison to Type of Loss

One way ANOVA is performed with level of loss as dependent variable and type of loss as independent variable. The same coding was used for the level of loss.

Table 14a: One way ANOVA descriptive of Level of Loss in Comparison to Type of Loss

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Congenital	78	3.13	1.273	.144	2.84	3.42	1	8
Acquired	93	3.33	2.055	.213	2.91	3.76	1	10
Total	171	3.24	1.741	.133	2.98	3.50	1	10

14b: Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
23.042	1	169	.000

Test of Homogeneity of Variances as explained earlier, tests the condition that the variances of both samples are equal. In this statistic, once again it indicates difference of variances in the population, and that is *Sig*. = 0.000.

Table 14c: ANOVA Table

Level of Loss	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.785	1	1.785	.588	.444
Within Groups	513.385	169	3.038		
Total	515.170	170			

In this ANOVA test once again there is not much difference between the two Mean Squares (1.785 and 3.038), resulting in a not significant difference (*F* = 0.588; *Sig*. = 0.444). This means that the null hypothesis cannot be rejected. Thus, the mean level of loss in congenital and acquired falls within 3 representing transradial. The "Robust Tests of Equality of Means" confirms that indeed the means are the same (*F* = 0.636; *Sig*. = 0.426).

Table 14d: Robust Tests of Equality of Means

	Statistic[a]	df1	df2	Sig.
Welch	.636	1	156.310	.426
Brown-Forsythe	.636	1	156.310	.426

a. Asymptotically F distributed.

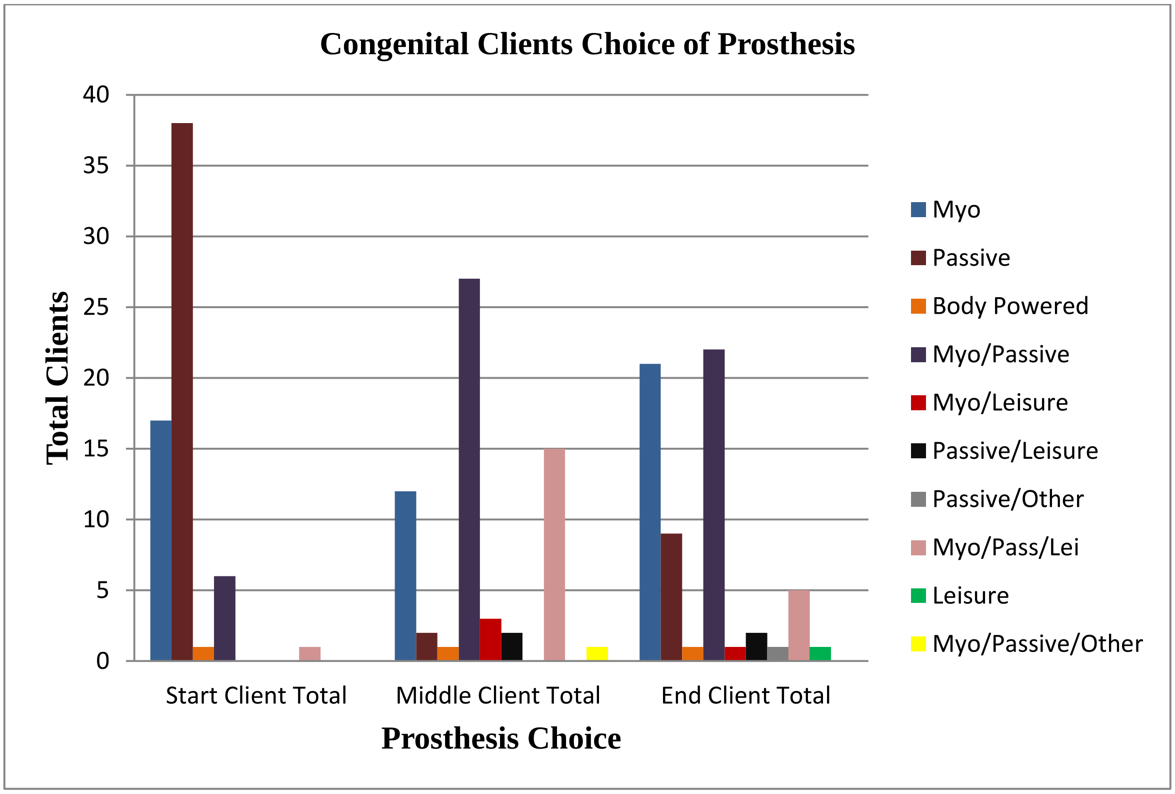
Choice of Prosthesis, Cost of Device and Type of Coverage

Out of a total of 212 clients a sample size of 118 clients was selected based on the criteria that the clients have at least 3 or more visit records and the period should not be less than 2 years. This is purposely to capture most of the active clients since they have frequent visit records for at least 2 years. From the sample size of 118 clients, there were 20 clients with missing records on the type of loss. Hence, the choice of prosthesis was determined by a sample size of 98 clients, of which 63 were congenital and 35 were acquired. Choice of prosthesis at first clinic visit represents the prosthesis chosen when a client was first fit. The prosthesis used at the median or middle year of clinic visits represents the prosthesis halfway through clinic visits. Lastly, the prosthesis currently used represents the prosthesis towards end of clinic visits which means the prosthesis chosen at client last clinic visit.

Table 15: Congenital Clients Choice of Prosthesis

Prosthesis Type	**Start Client Total**	**Middle Client Total**	**End Client Total**
Myo	17	12	21
Passive	38	2	9
Body Powered	1	1	1
Myo/Passive	6	27	22
Myo/Leisure	0	3	1
Passive/Leisure	0	2	2
Passive/Other	0	0	1
Myo/Pass/Lei	1	15	5
Leisure	0	0	1
Myo/Passive/Other	0	1	0
Total	**63**	**63**	**63**

Figure 11: Congenital Clients Choice of Prosthesis



Referring to table 15 and figure 11 above, most congenital clients at the start of clinic visits are small children fit only with passive prosthesis. They make up a total of 38 clients out of 63 valid congenital populations. Clients who used only myoelectric were 17 in total. Only 1 client at the start of clinic visit used a body powered prosthesis. A total of 6 clients were using a combination of myoelectric/passive prosthesis whilst only 1 client used a combination of myoelectric/passive/leisure prosthesis.

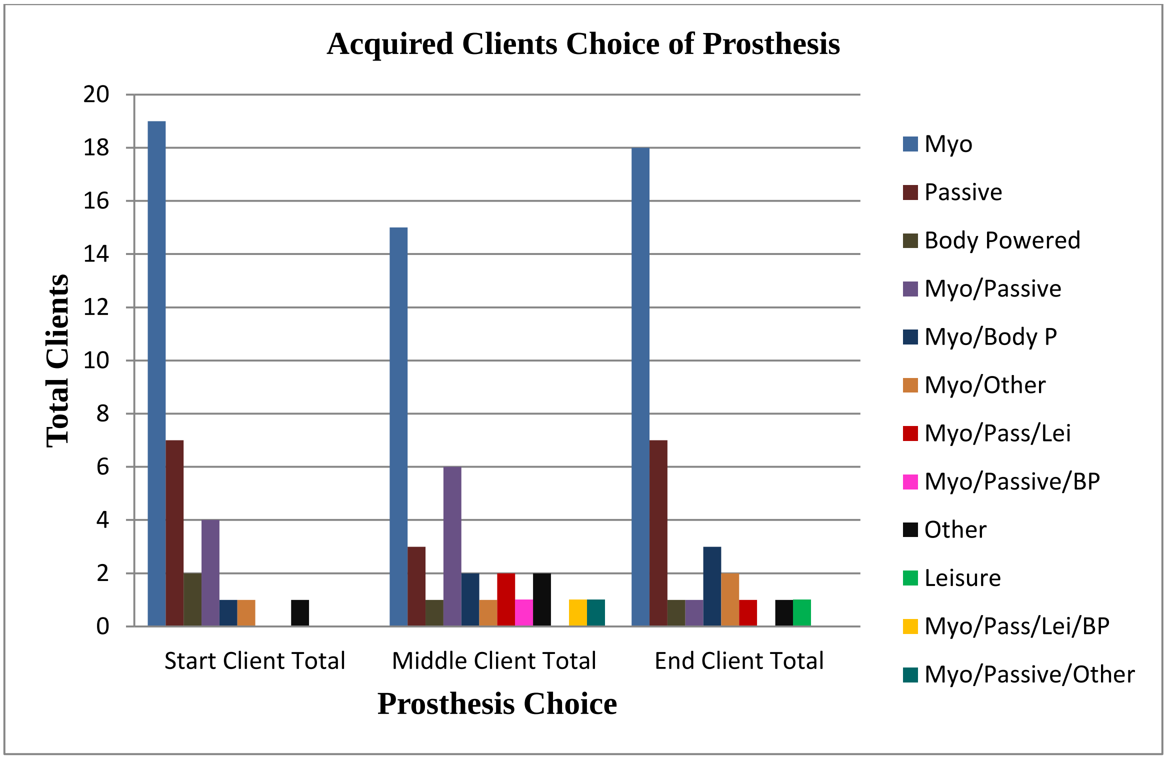
Halfway through the clinic visits, 12 congenital clients were only using myoelectric prosthesis and 2 were using a passive prosthesis. Also only 1 client used a body powered prosthesis whilst a total of 27 clients used a combination of myoelectric/passive prosthesis. There were a total of 15 clients who used a combination of myoelectric/passive/leisure prosthesis whilst 1 client used a combination of myoelectric/passive/other prosthesis.

Towards the end of clinic visits, 21 congenital clients used only myoelectric prosthesis and 1 client was using body powered prosthesis. Those who used passive only were 9 in total, whilst 1 client also used leisure prosthesis. A total of 22 clients were using a combination of myoelectric/passive prosthesis whereas only 2 clients used a combination of passive/leisure prosthesis. Also a total of 5 clients used a combination of myoelectric/passive/leisure prosthesis whilst a pair of client each used a combination of myoelectric/leisure and passive/other prosthesis respectively.

Table 16: Acquired Clients Choice of Prosthesis

Prosthesis Type	**Start Client Total**	**Middle Client Total**	**End Client Total**
Myo	19	15	18
Passive	7	3	7
Body Powered	2	1	1
Myo/Passive	4	6	1
Myo/Body P	1	2	3
Myo/Other	1	1	2
Myo/Pass/Lei	0	2	1
Myo/Passive/BP	0	1	0
Other	1	2	1
Leisure	0	0	1
Myo/Pass/Lei/BP	0	1	0
Myo/Passive/Other	0	1	0
Total	**35**	**35**	**35**

Figure 12: Acquired Clients Choice of Prosthesis



Most acquired clients at the start of clinic visits preferred only myoelectric prosthesis. They make up a total of 19 clients out of 35 sampled acquired populations. Clients who used only passive prostheses were 7 in total whilst 1 client used other prostheses. Also only 2 clients at the start of clinic visits were using body powered prosthesis. A total of 4 clients were using a combination of myoelectric/passive prosthesis whilst a pair of client each used a combination of myoelectric/body powered and myoelectric/other prosthesis respectively.

Halfway through the clinic visits, 15 acquired clients were only using myoelectric prosthesis and 3 were using passive prosthesis. Also 1 client only used body powered prosthesis whilst 2 used other prosthesis. A total of 6 clients used a combination of myoelectric/passive, whereas a pair of 2 clients used myoelectric/body powered and myoelectric/passive/leisure prosthesis respectively. The combination of myoelectric/other, myoelectric/passive/body powered, myoelectric/passive/other, and electric/passive/leisure/body powered prosthesis were used by only 1 client each.

Towards the end of clinic visits, about half of acquired clients used only myoelectric prosthesis. They make up a total of 18 out of 35 sampled populations. Clients who used passive only were 7 in total whilst 1 client each used other and leisure prosthesis only. Body powered prosthesis only was also used by 1 client at the end of clinic visits. A total of 3 clients were using a combination of myoelectric/body powered prosthesis whilst only 1 client used myoelectric/passive prosthesis. There were 2 clients who used a combination of myoelectric/other prosthesis and 1 client who used myoelectric/passive/leisure towards the end of clinic visit.

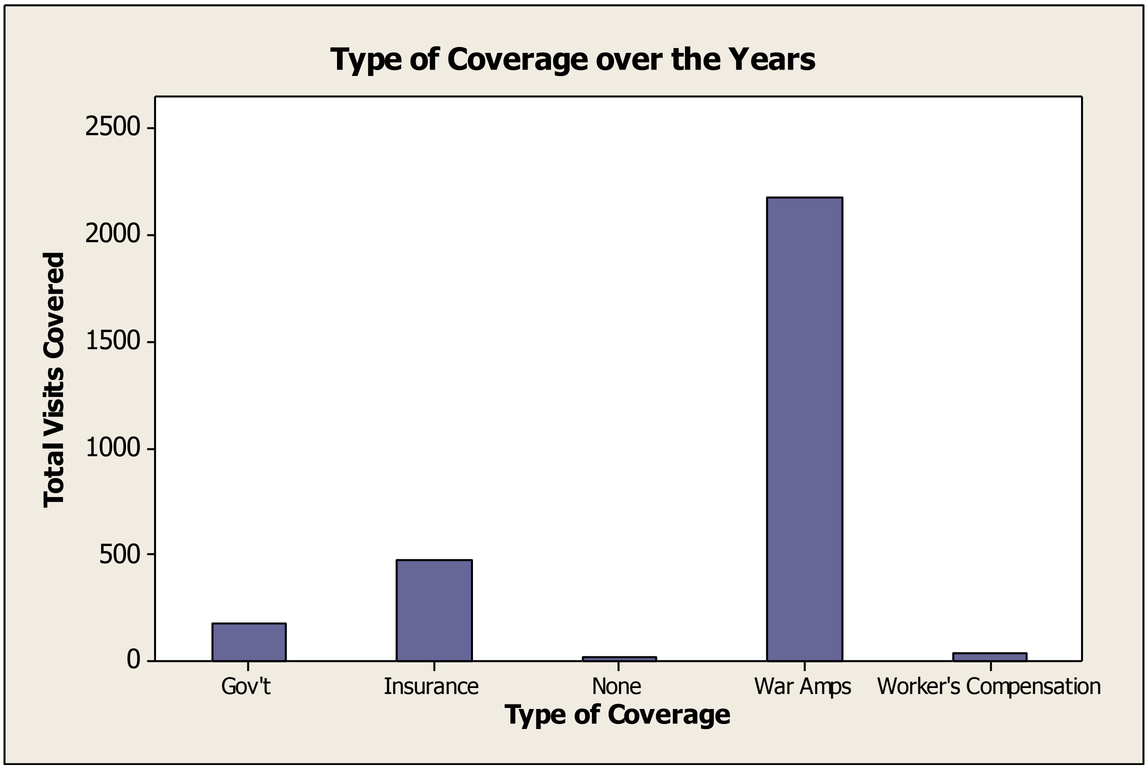
Type of Coverage

Clients who have visited the clinic since 1981 came with different forms of financial coverage for their expenses. Table 17 below gives a list of clients' coverage at the clinic.

Table 17: Types of Financial Coverage for Total Clinic Visits

Type of Coverage	Frequency	Percent	Valid Percent	Cumulative Percent
Gov't	179	6.2	6.2	6.2
Insurance	474	16.5	16.5	22.7
None	21	.7	.7	23.4
War Amps	2172	75.4	75.4	98.8
Worker's Compensation	34	1.2	1.2	100.0
Total	2880	100.0	100.0	

Figure 13: Types of Financial Coverage for Total Clinic visits



From figure 13 above, it is clear that in the entire history of the clinic War Amps has been the main source of financial coverage for clients. From 1985 to date War Amps has provided 75.4% of the total financial coverage related to visits at the clinic amounting to 2172 out of 2880 client visits. The second highest were clients who came in with insurance coverage. They accounted for a total coverage for visits of 474 out of 2880 representing 16.5%. There were 179 client visits under the coverage of the government (both federal and provincial). This represents 6.2% of the total coverage at the clinic. There were also 34 client visits under worker's compensation coverage representing 1.2% of the total clinic coverage. Lastly, clients with no form of coverage (none) comprised a total of 21 visits, representing 0.7% of the total coverage at the clinic.

The tables and figures below give the breakdown of the types of coverage provided and total clients covered across the decades the clinic has been in existence.

Table 18a: Financial Coverage for Total Visits across Decades

Coverage	**1980s**	**1990s**	**2000s**
Gov't	8	35	136
War Amps	266	676	1230
Insurance	0	13	461
Worker's Compensation	0	0	34
None	0	0	21

Table 18b: Financial Coverage for Total Clients across Decades

Coverage for Clients	**1980s**	**1990s**	**2000s**
Gov't	1	4	21
War Amps	17	34	104
Insurance		10	33
Worker's Compensation			10
None			8

As presented in the tables above and figures below; in the 1980's only War Amps and the government provided coverage to client visits. War Amps provided 266 out of the total 274 visits, representing 97.1% coverage for 17 clients. There were only 8 client visits under the government making up 2.9% of total coverage for 1 client.

Figure 14a: Financial Coverage for Total Visits across Decades

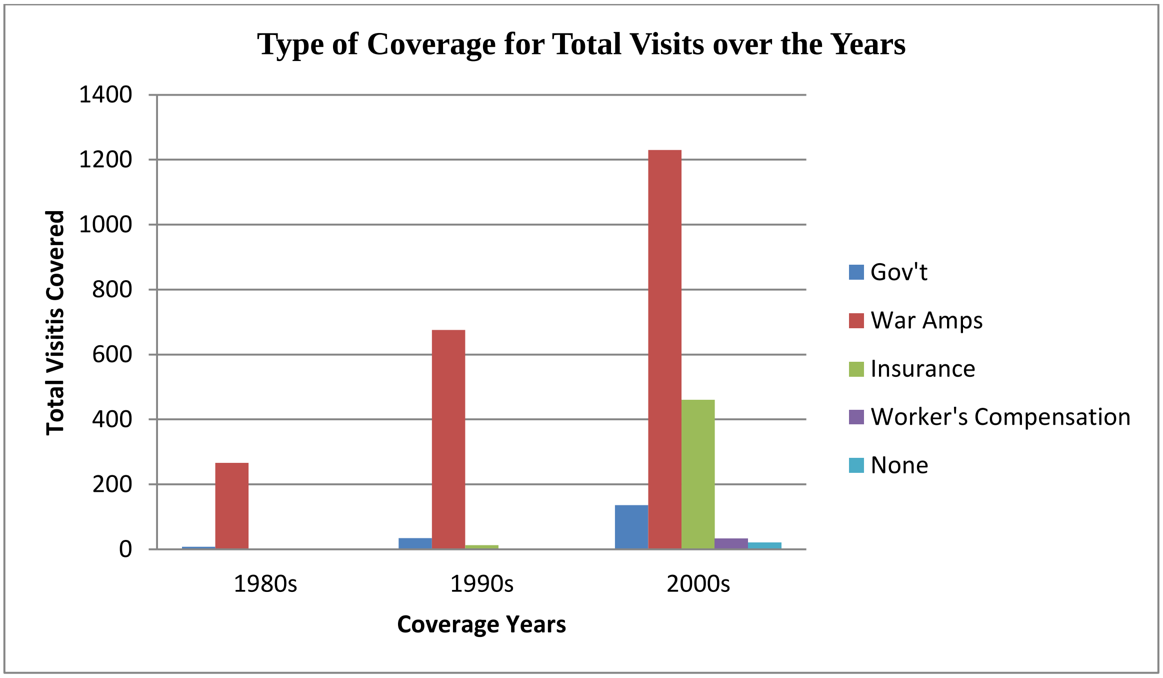
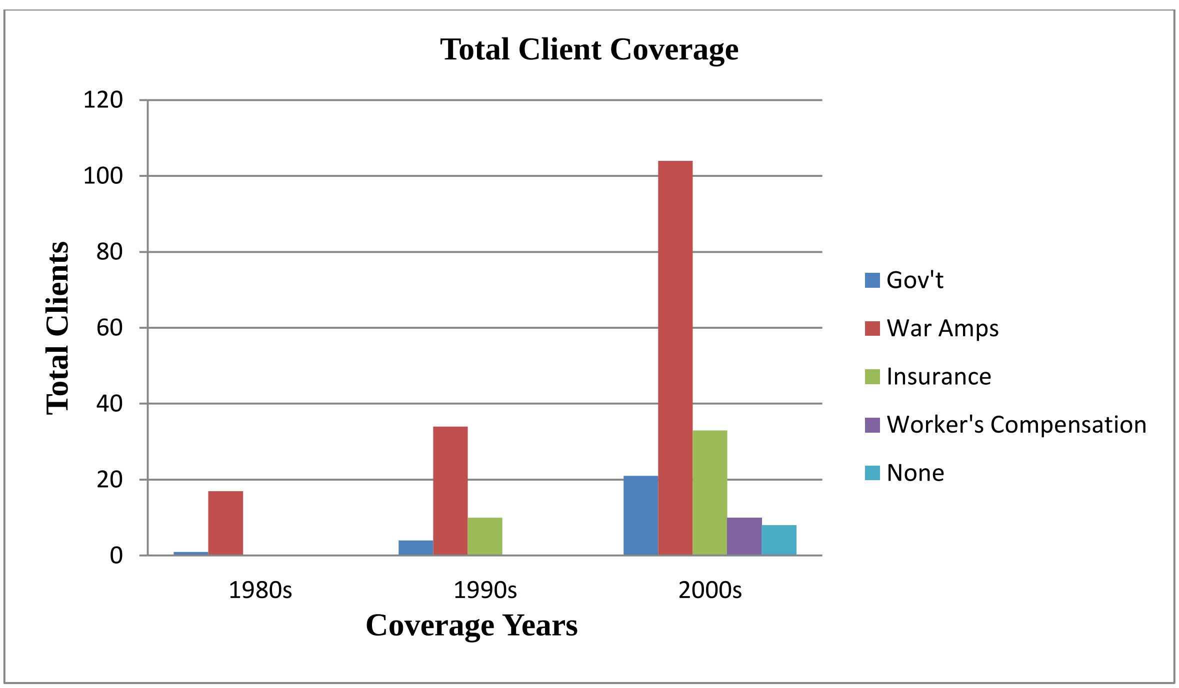


Figure 14b: Financial Coverage for Total Clients across Decades



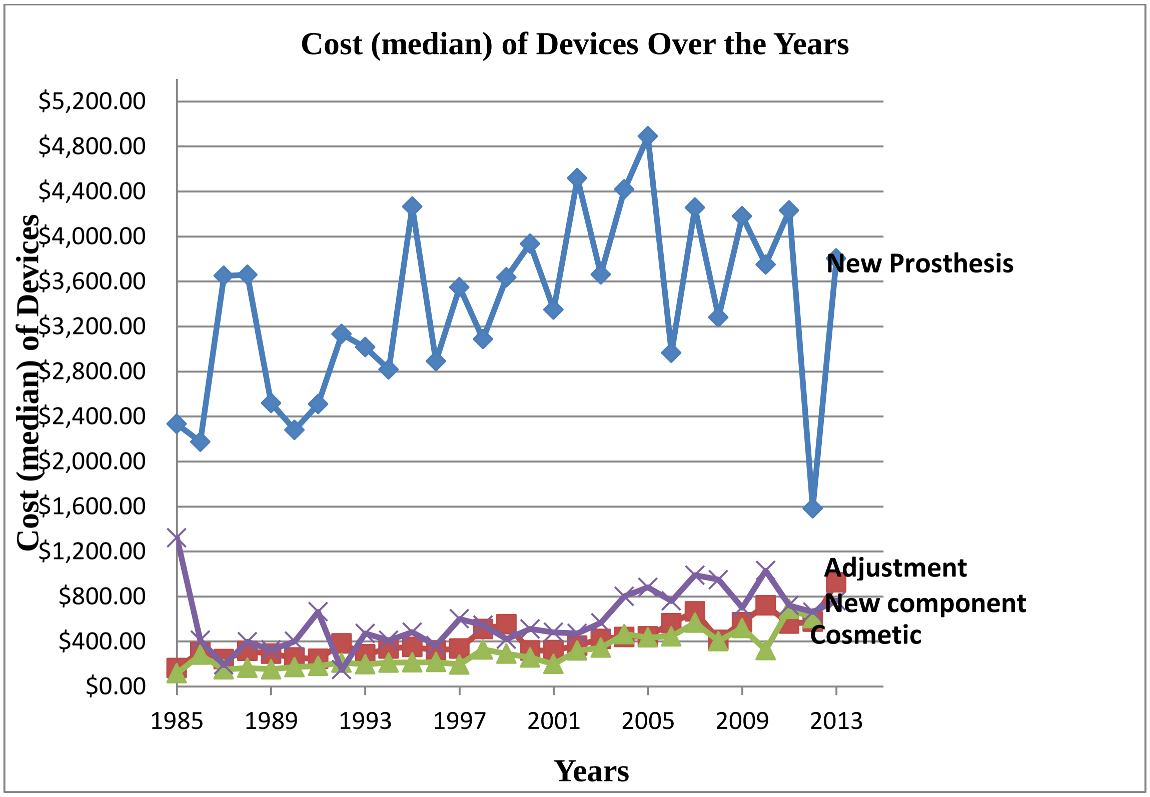
In the 1990’s War Amps was again the main source of financial coverage for clients. War Amps provided 93.4% of the total financial coverage at the clinic amounting to 676 out of 724 client visits for 34 clients. In terms of visits, the second highest were clients who came with government coverage. They accounted for a total coverage visit of 35 out of 724 representing 4.8% for 4 clients. There were 13 client visits made by 10 clients with insurance coverage. This represents 1.8% of the total coverage at the clinic.

In the years since 2000 War Amps still remains the main source of financial coverage for clients visit at the clinic. War Amps provided 65.4% of the total visits coverage at the clinic amounting to 1230 out of 1882 visits for 104 clients. The second highest were clients who came in under insurance coverage. They accounted for a total visit coverage of 461 out of 1882 representing 24.5% for 33 clients. There were 136 client visits under the coverage of the government (both federal and provincial). This represents 7.2% of the total visits coverage at the clinic for 21 clients. There were also 34 visits under workers compensation coverage made by 10 clients. This represents 1.8% of the total clinic coverage. Lastly, clients with no form of coverage (none) comprised a total of 21 visits made by 8 clients, representing 1.1% of the total coverage at the clinic.

Table 19: Cost (median) of Devices over the Years

Year	New Prosthesis	Adjustment	Cosmetic gloves	New component
1985	$2,333.10	$164.54	$118.00	$1,322.00
1986	$2,176.05	$306.98	$282.38	$410.60
1987	$3,650.59	$243.35	$152.36	$191.09
1988	$3,660.00	$317.00	$166.50	$397.35
1989	$2,519.50	$291.75	$153.00	$325.00
1990	$2,280.00	$256.89	$172.50	$402.50
1991	$2,509.80	$245.00	$183.75	$663.30
1992	$3,132.08	$382.55	$212.75	$149.00
1993	$3,016.00	$285.00	$198.00	$471.66
1994	$2,817.50	$337.50	$213.00	$411.00
1995	$4,265.50	$353.00	$214.00	$483.75
1996	$2,890.00	$321.50	$217.75	$363.00
1997	$3,549.00	$338.25	$195.65	$600.50
1998	$3,086.90	$510.50	$330.00	$546.00
1999	$3,637.41	$553.00	$291.00	$420.00
2000	$3,936.00	$319.00	$258.50	$511.00
2001	$3,350.00	$322.50	$200.00	$482.00
2002	$4,519.00	$363.50	$320.00	$472.00
2003	$3,663.00	$423.00	$345.00	$565.50
2004	$4,418.47	$440.00	$465.80	$802.15
2005	$4,889.77	$446.33	$436.44	$881.36
2006	$2,964.86	$563.04	$446.53	$760.00
2007	$4,256.18	$666.93	$566.87	$989.55
2008	$3,281.64	$414.20	$404.20	$949.00
2009	$4,180.89	$571.80	$519.69	$700.30
2010	$3,751.59	$722.70	$323.54	$1,030.21
2011	$4,232.12	$558.48	$691.47	$721.18
2012	$1,583.44	$575.83	$606.60	$663.00
2013	$3,805.47	$927.01		$761.60

Figure 15: Cost (median) of Devices over the Years



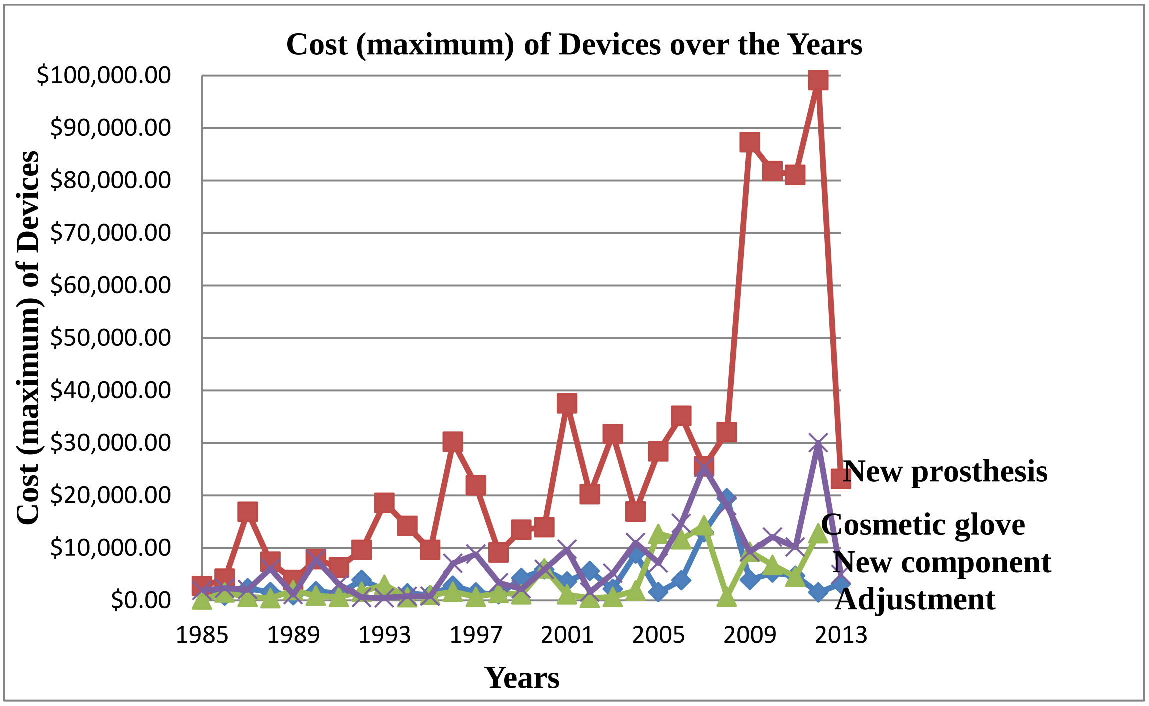
From the figure above it is obvious the cost of devices over the years does not have a steady trend. The median cost of a new prosthesis in 1985 was $2,333 and in 2013 it was $3,805, a difference of $1472 increment. However, in between the 3 decades the cost of device has been fairly variable with a cost as low as $1,583 in 2012 and as high as $4,889 in 2005. The cost of adjustment was fairly steady compared to that of new prosthesis. The lowest adjustment cost was $164 in 1985 and the highest $ 927 in 2013. The difference in adjustment cost over the decades is $762. Cosmetic gloves also showed a similar trend to that of adjustment. The cost of cosmetic gloves was at its lowest price of $118 in 1985 and highest in 2011 with a price of $691. The difference over the decades is $573. The cost of new components showed a much different trend compared to the other devices. Surprisingly, the cost of new components was highest in

1985 at a price of $1,322. In 2013 the cost was $ 761 indicating a tremendous reduction in price by $561 over a period of 3 decades. However the lowest cost of new component was $149 in 1992.

Table 20: Cost (maximum) of Devices over the Years

Year	**Adjustment**	**New prosthesis**	**Cosmetic glove**	**New component**
1985	$1,948.95	$2,717.24	$142.00	$1,868.48
1986	$882.50	$4,117.27	$1,497.50	$2,317.47
1987	$2,289.99	$16,868.65	$677.02	$2,033.53
1988	$1,578.50	$7,349.27	$430.00	$6,066.00
1989	$965.00	$3,849.65	$1,922.50	$1,079.88
1990	$1,756.50	$7,812.00	$878.50	$7,802.46
1991	$1,317.50	$6,285.00	$674.25	$3,037.50
1992	$3,853.37	$9,587.86	$1,640.00	$526.00
1993	$2,040.00	$18,594.74	$2,974.10	$471.66
1994	$1,320.00	$14,164.35	$582.73	$791.00
1995	$990.00	$9,598.00	$990.00	$796.00
1996	$2,787.50	$30,200.50	$1,633.50	$7,061.73
1997	$1,488.40	$21,943.00	$660.00	$8,793.80
1998	$1,120.00	$9,132.80	$1,396.00	$3,350.00
1999	$4,215.00	$13,443.80	$1,136.00	$2,160.00
2000	$5,868.91	$13,958.66	$6,101.00	$5,868.91
2001	$3,589.00	$37,545.00	$1,124.00	$9,703.51
2002	$5,561.00	$20,194.50	$438.00	$1,575.00
2003	$2,156.00	$31,685.24	$661.00	$5,147.00
2004	$8,864.00	$16,893.40	$1,836.40	$11,005.46
2005	$1,542.52	$28,368.64	$12,666.58	$7,139.66
2006	$3,830.50	$35,127.28	$11,602.65	$14,641.13
2007	$12,962.50	$25,501.56	$14,274.97	$25,348.38
2008	$19,426.80	$32,045.07	$711.82	$18,007.96
2009	$3,887.60	$87,275.03	$9,261.80	$9,261.80
2010	$5,250.38	$81,771.71	$6,745.41	$12,066.22
2011	$4,684.12	$81,033.07	$4,469.43	$10,152.50
2012	$1,474.50	$99,109.70	$12,768.95	$30,014.44
2013	$3,153.90	$23,136.44		$4,934.67

Figure 16: Cost (maximum) of Devices over the Years

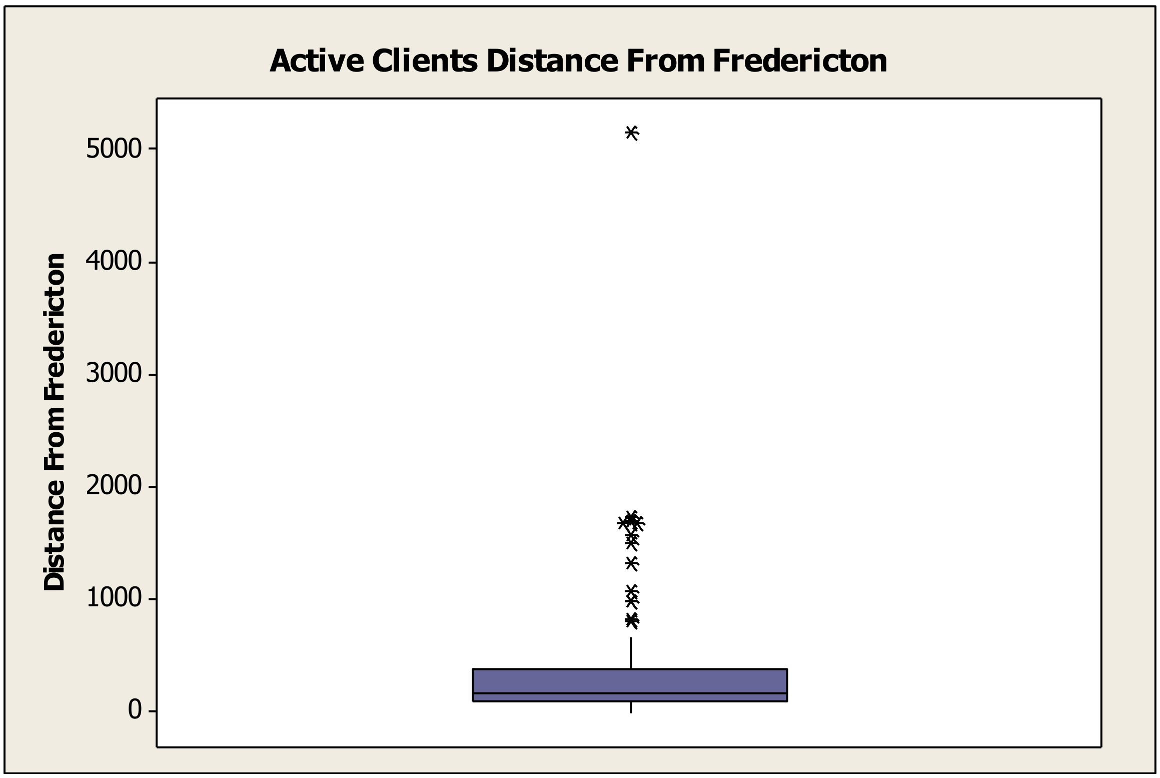


The maximum cost of devices in the figure above shows a similar trend in almost all the devices. The maximum cost of new prosthesis was $2,717 in 1985 at its lowest and highest in 2012 at a price of $99,109, being the cost of one above-elbow prosthesis required due to traumatic limb loss. However, over the 3 decades, the cost of new prosthesis has seen a major rise and fall in pattern. The cost of cosmetic gloves was $142 in 1985 but increased to its highest price of $14,274 in 2007 and then reduced gradually until in 2012 rising to a cost price of $12,768. The cost of new component was $1,868 in 1985 but was highest in 2012 at a price of $30,014 and lowest in 1993 at a price of $471. Between 1992 and 1995 the cost of a new component was low and fairly stable. The maximum cost of adjustment was also similar in trend to new component. In 1985 the cost was $1,948 and at its highest in 2008 at a price of $19,426. However its lowest cost was in 1995 at a price of $990.

Visit Trends for Active Clients (2013)

Most of the client visits were travels made from within New Brunswick. The median travel distance by a client was 179km. Travelled distance between the 3rd quartile 388.5km and the upper whiskers 667km were mostly clients from Nova Scotia (NS).

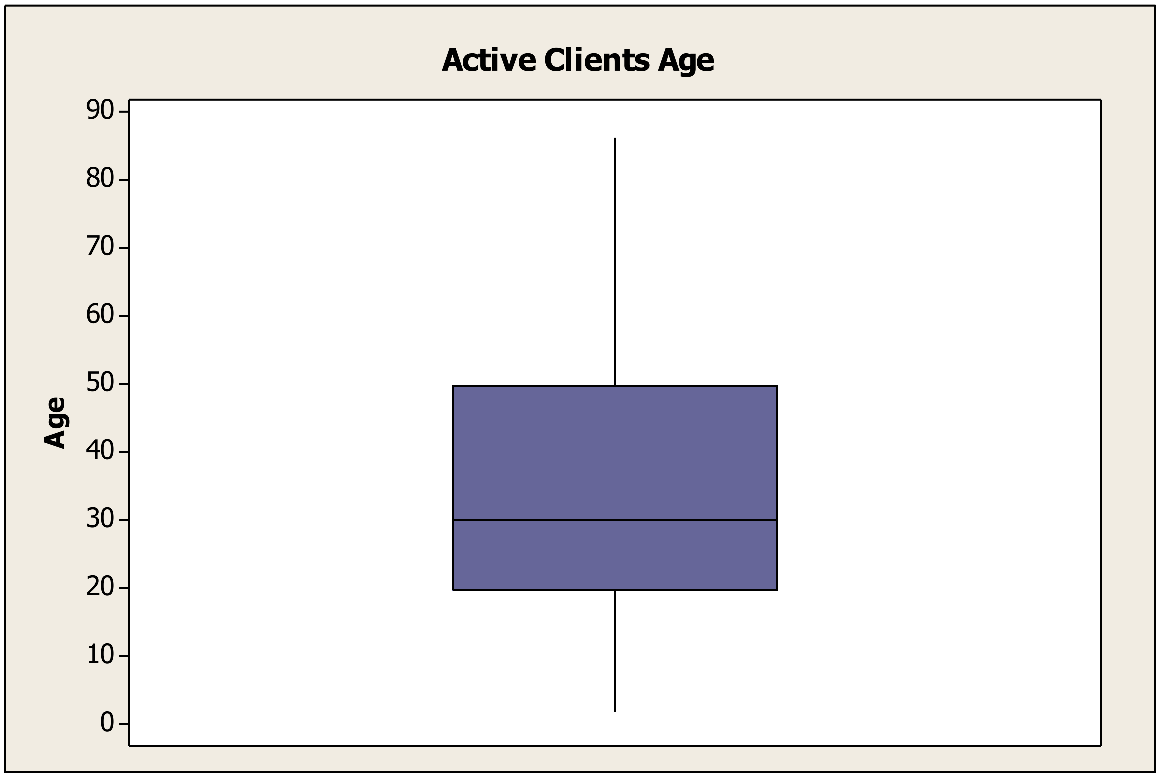
Figure 17: Boxplot of Active Clients Distance Travel from Fredericton



Distance travelled by clients from Prince Edward Island (PEI) fell between the inter quartile (278.5km) and the 3rd quartile (388.5km). Almost all the outliers were distance travelled by clients from Newfoundland and Labrador (NFLD) with the exception of the single outlier further up which is from British Columbia (BC). In all about 30% of the active client visits were made by clients from PEI, NS and NFLD.

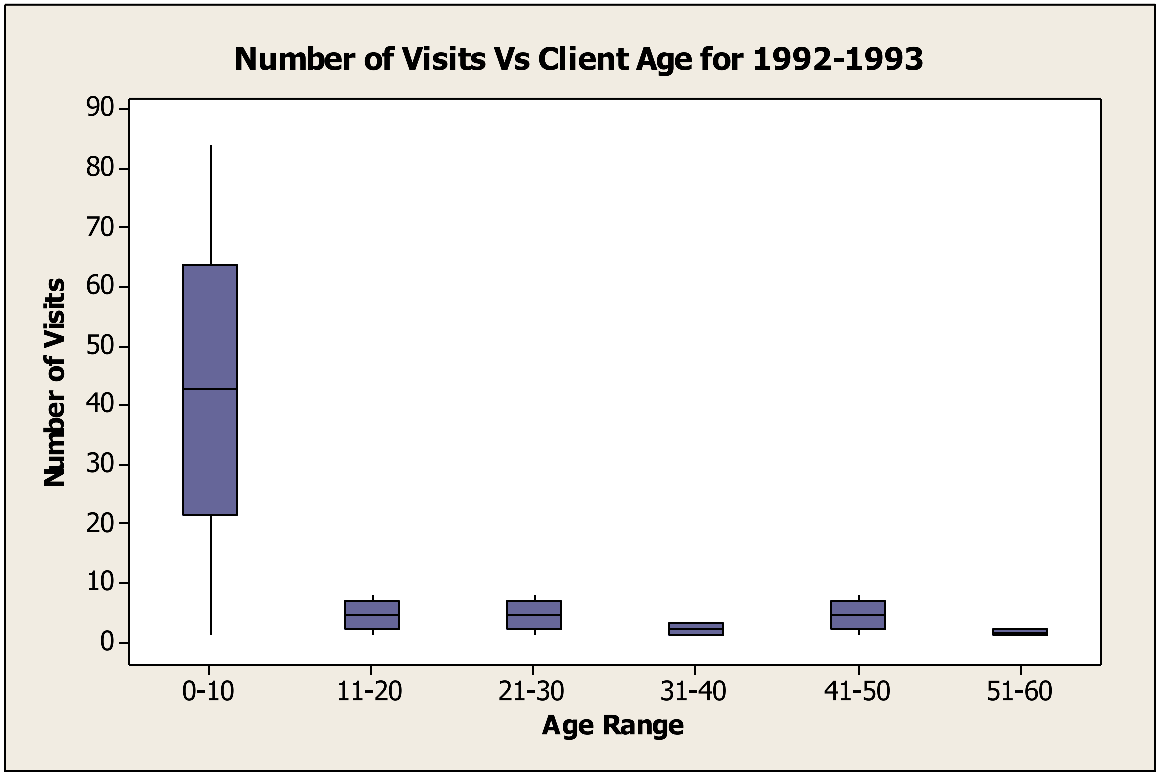
Amongst the active clients the age ranges from 2 years (youngest) to 86 years (oldest). However the median client age was 30 years. About 52% of the active clients (68) are below the age of 30 years. Children under the age of 18 years make up 24% representing a total of 31 active clients.

Figure 18: Boxplot of Active Clients Age



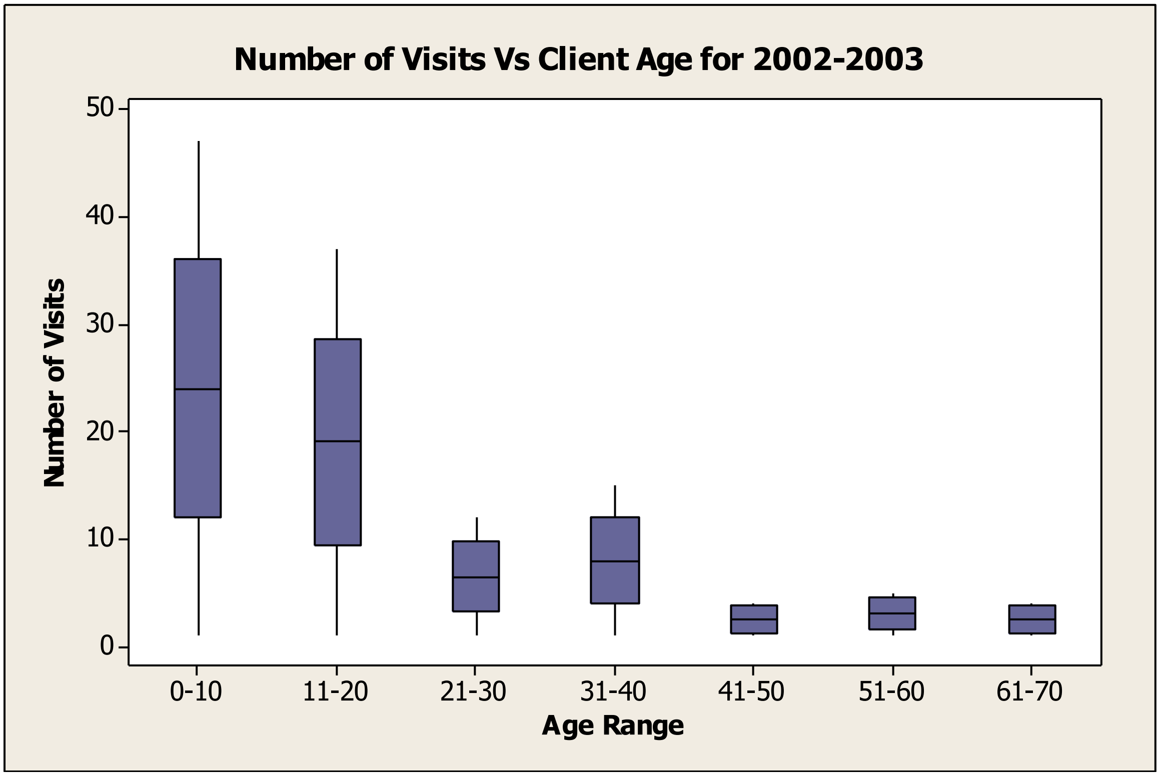
Between 1992 and 1993 clients within the age range of 0 to10 years made the most visits to the clinic. They comprised a total of 84 visits of which 21% were for acquired and 79% were for congenital clients with a median of 42.5 visits. Clients ranging from ages 11 to 20, 21 to 30 and 41 to 50 years made a total 8 visits each with a median of 4.5 visits. There were only 3 visits from clients 31 to 40 years and 2 from clients aged 51 to 60 years. In all there were a total of 113 visits made by 41 clients.

Figure 19: Boxplot of Number of Visits against Clients Age (1992-1993)



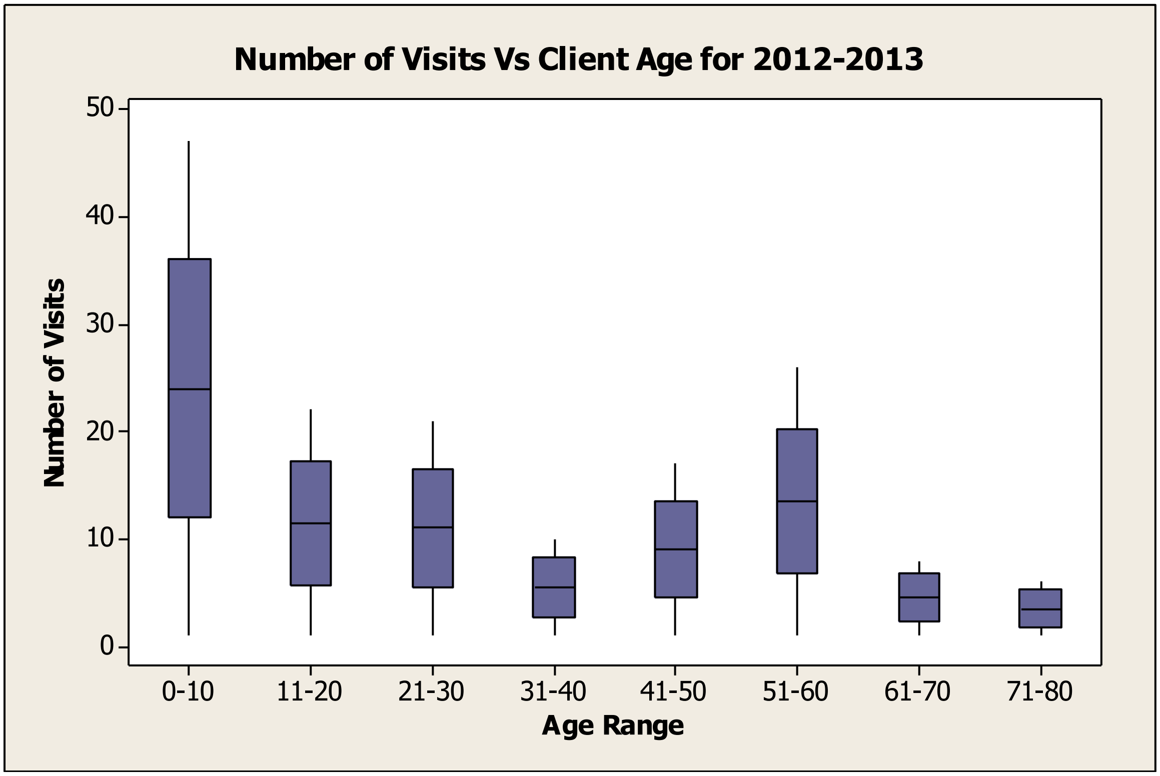
In the years 2002 to 2003, there were a total of 124 visits made by 63 clients. Out of the 124 visits, 47 of them were made by clients aged 0 to 10 years and 37 by those aged 11 to 20 years. The median numbers of visits between these two age groups vary from 24 in 0 to 10 years and 19 in those aged 11 to 20 years. There were a total of 15 visits from clients aged 31 to 40 years with a median of 8 visits whilst clients aged 21 to 30 made a total visit of 12 with a median of 6.5 visits. There was a low record of visits from clients aged 41 to 50 years (4 visit), 51 to 60 years (5 visits) and 61 to 70 years (4 visits).

Figure 20: Boxplot of Number of Visits against Clients Age (2002-2003)



In comparison to the years 1992 to1993 and 2002 to 2003, there were more client visits from 2012 to 2013. A total of 157 visits were made by 48 clients. Although clients aged 0-10 years still made the most number of 47 visits, the variability in the number of visits across the ages was better spread with total visit from clients aged 51 to 60 years reaching a record high of 26. Also in general, the number of visits from older clients aged 41 years and above was higher during the years 2012 to 2013.

Figure 21: Boxplot of Number of Visits against Clients Age (2012-2013)



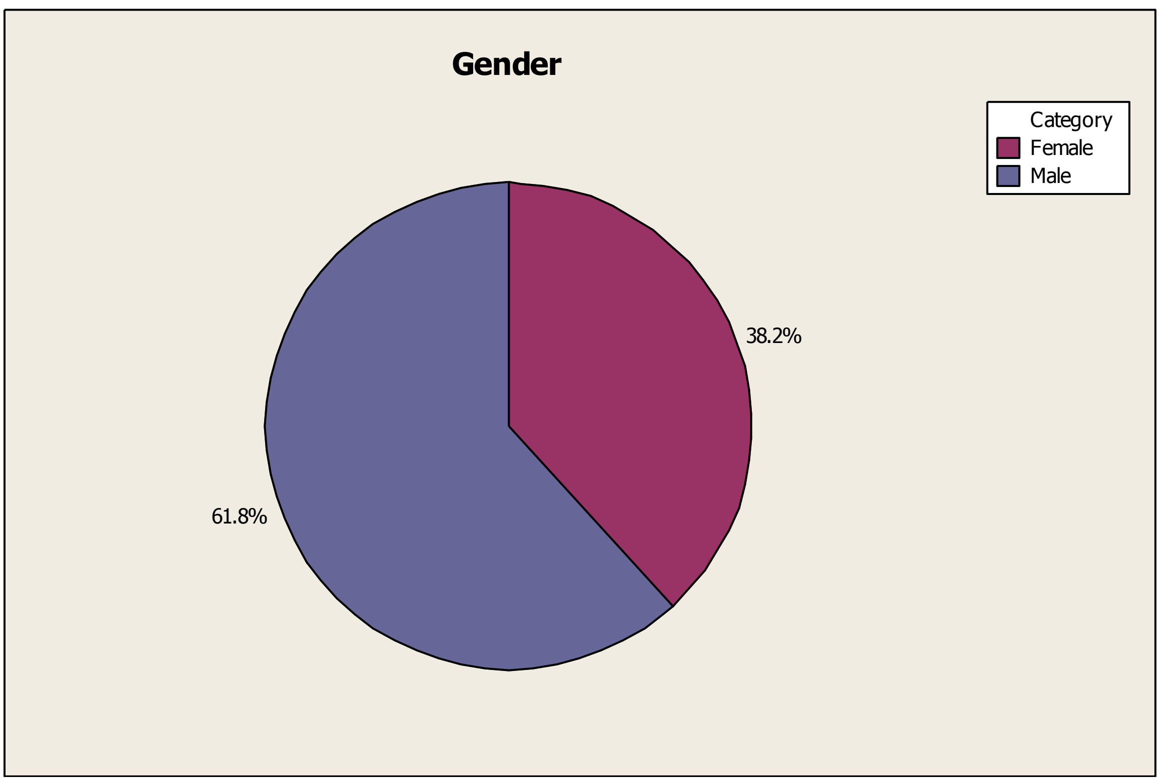
Description of Subset of Working Age Anthropometric Data

The subset for working age clients comprised of 34 clients. Out of these 13 clients were females and 21 were males, representing 38.2% and 61.8% respectively.

Table 21: Frequency Table of Gender for Subset Group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	21	61.8	61.8	61.8
	Female	13	38.2	38.2	100.0
	Total	34	100.0	100.0	

Figure 22: Graph of Gender for Subset Group



Within the subset population there were 16 congenital and 18 acquired clients. This represents 47.1% and 52.9% respectively as shown in table below.

Table 22: Frequency Table of Type of Loss for Subset Group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Congenital	16	47.1	47.1	47.1
	Acquired	18	52.9	52.9	100.0
	Total	34	100.0	100.0	

Figure 23: Graph of Type of Loss for Subset Group

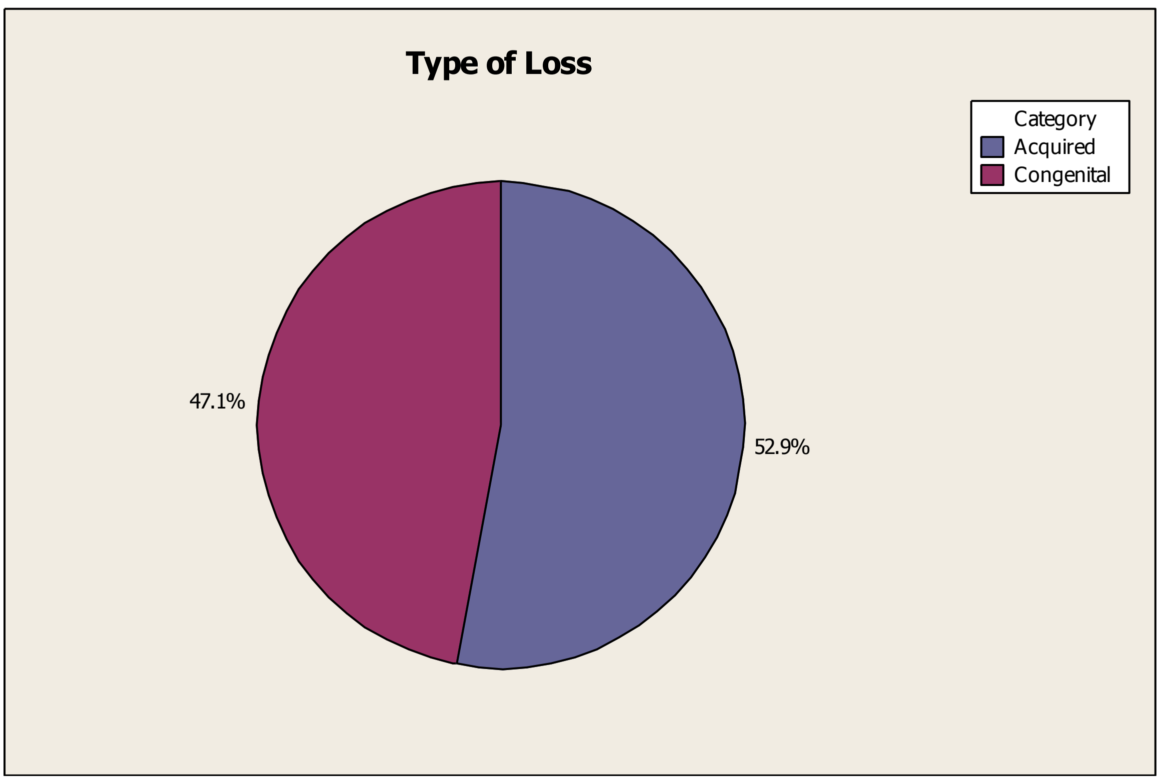
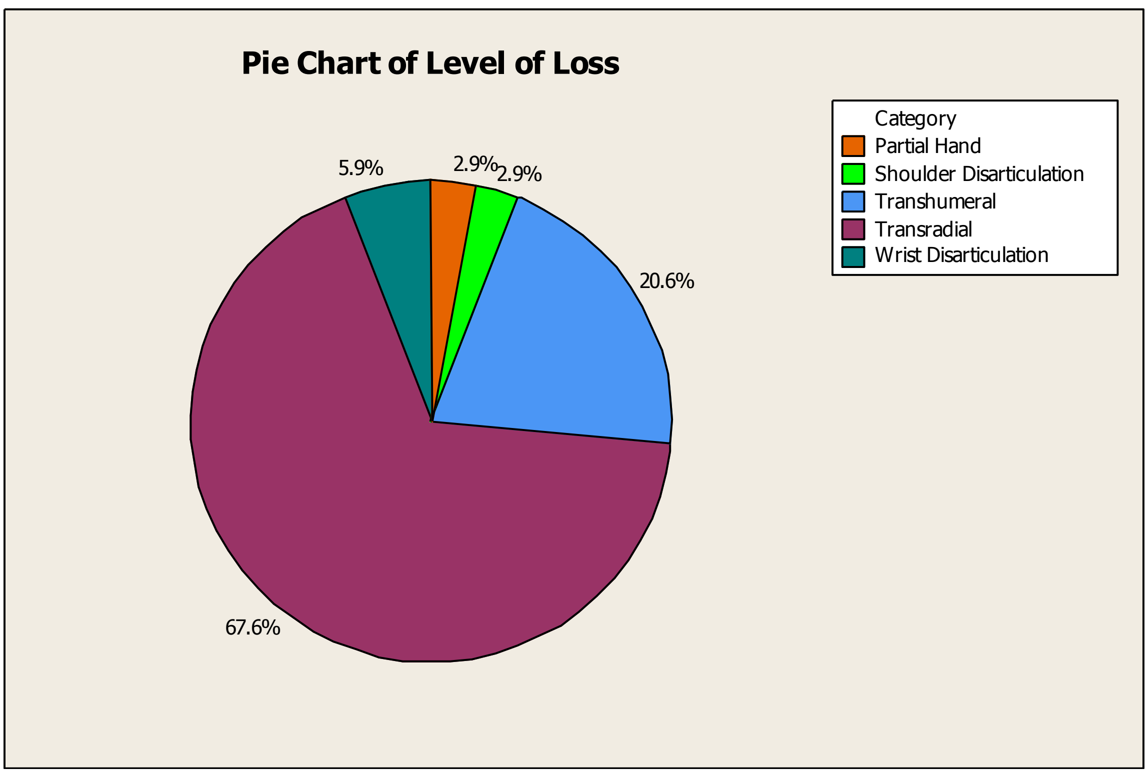


Table 23: Frequency Table of Level of Loss for Subset Group

Level of Loss		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Partial Hand	1	2.9	2.9	2.9
	Wrist Disarticulation	2	5.9	5.9	8.8
	Transradial	23	67.6	67.6	76.5
	Transhumeral	7	20.6	20.6	97.1
	Shoulder Disarticulation	1	2.9	2.9	100.0
	Total	34	100.0	100.0	

Figure 24: Graph of Level of Loss for Subset Group

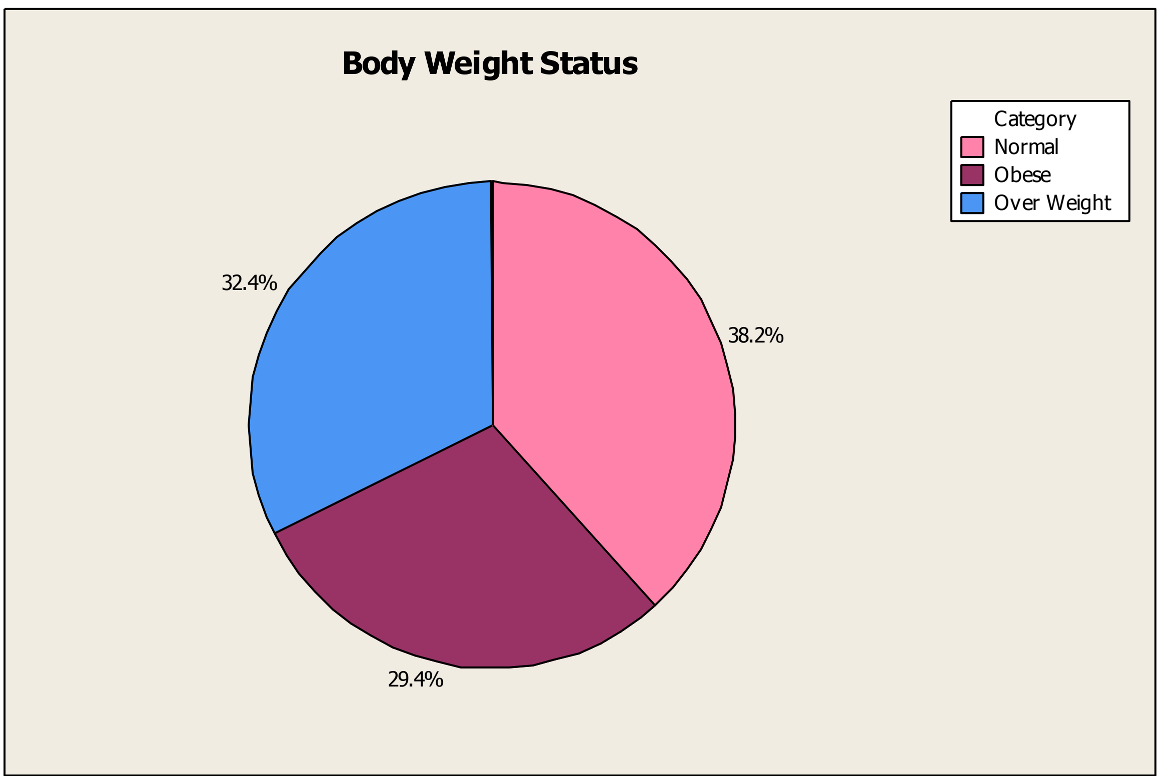


Out of the 34 clients within the subset, 23 were transradial level of loss representing 67.6% valid cases. There were 7 transhumeral representing 20.6%, with 2 wrist disarticulation representing 5.9%. There was also 1 partial hand and shoulder disarticulation representing 2.9% each.

Table 24: Frequency Table of Body weight Status for Subset Group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	13	38.2	38.2	38.2
	Overweight	11	32.4	32.4	70.6
	Obese	10	29.4	29.4	100.0
	Total	34	100.0	100.0	

Figure 25: Graph of Body Weight Status for Subset Group



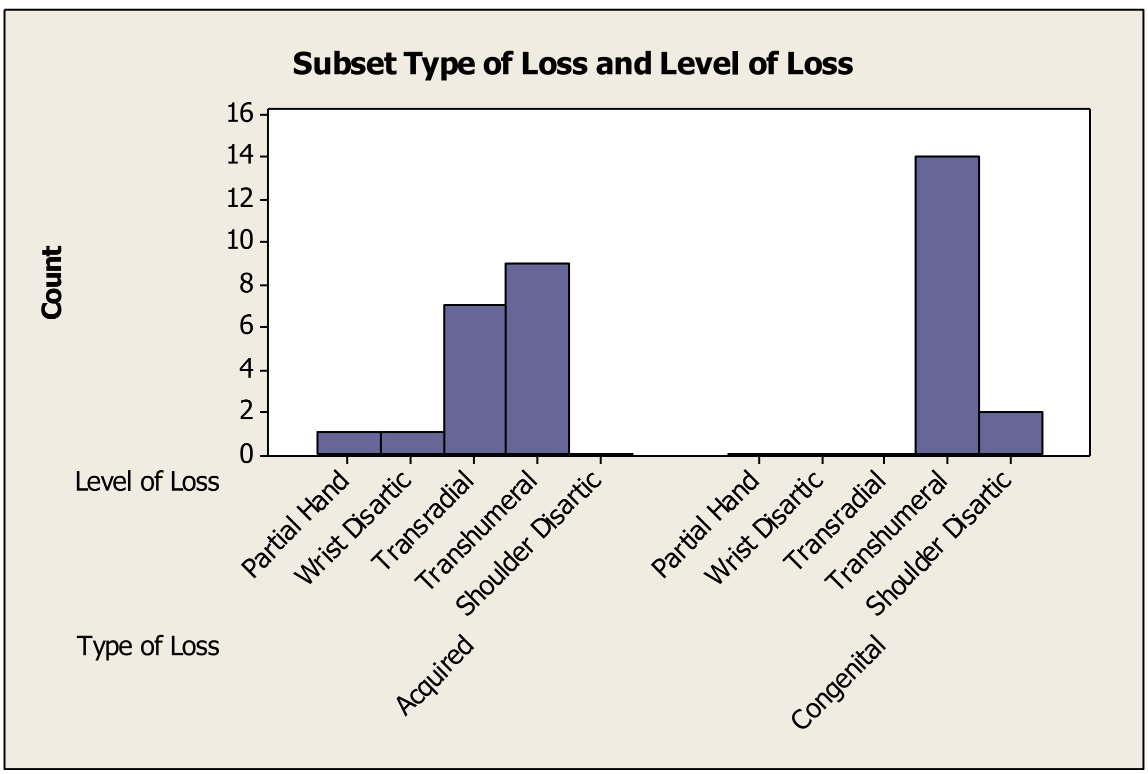
The BMI calculated values were categorized as underweight ≤ 18, normal = ≥18 to < 25, overweight = ≥ 25 to < 30 and Obese ≥ 30. From the subset population, 38.2%

were of normal body weight status representing 13 clients. There were 10 clients with obese body weight representing 29.4% whilst the remaining 11 clients were overweight representing 32.4%.

Table 25: Cross Tabulation of Level of Loss and Type of Loss

		Type of Loss		Total
		Congenital	Acquired	
Level of Loss	Partial Hand	0	1	1
	Wrist Disarticulation	2	0	2
	Transradial	14	9	23
	Transhumeral	0	7	7
	Shoulder Disarticulation	0	1	1
Total		16	18	34

Figure 26: Comparison Graph of Level of Loss and Type of Loss

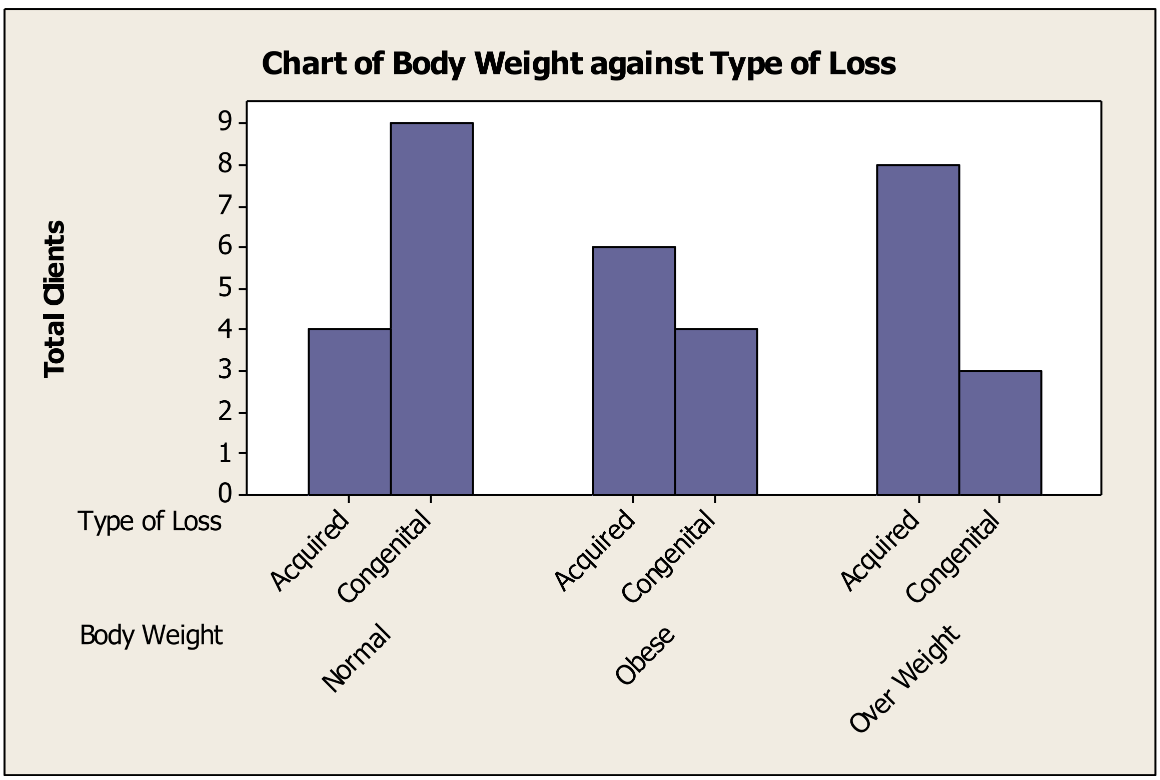


The cross tabulation of level of loss and type of loss shows that transradial level of loss is common in both congenital and acquired clients followed by transhumeral.

Table 26: Cross tabulation of Body Weight Status and Type of Loss

		Type of Loss		Total
		Congenital	Acquired	
Body weight Status	Normal	9	4	13
	Overweight	3	8	11
	Obese	4	6	10
Total		16	18	34

Figure 27: Comparison Graph of Body Weight Status and Type of Loss



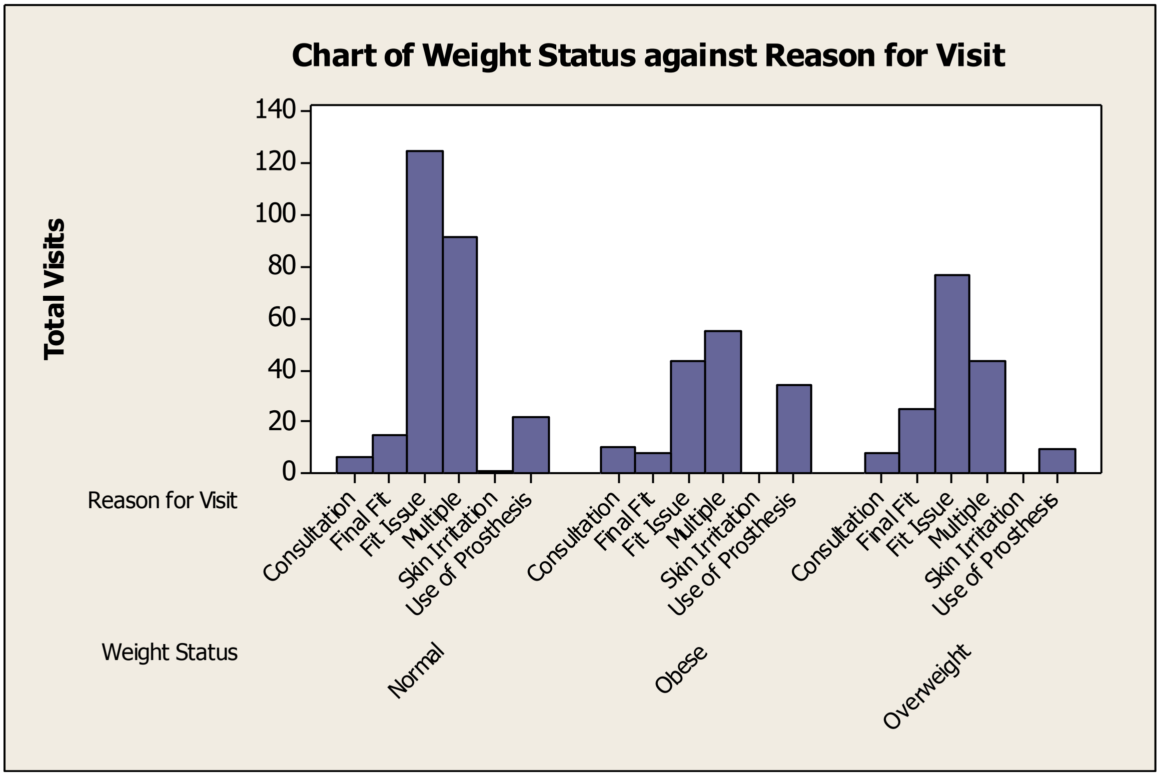
The cross tabulation of body weight status and type of loss shows that the majority of congenital clients (total of 9) were of normal body weight whilst in the acquired only a few (total of 4) were of normal body weight. Most acquired clients were overweight (total of 8 clients) and obese (total of 6 clients). Within the congenital clients 3 were overweight whilst the remaining 4 were obese.

Table 27: Cross Tabulation of Reason for Visit and Weight Status

		Weight Status			Total
		Normal	Obese	Overweight	
Reason for Visit	Fit Issue	125	43	77	245
	Consultation	6	10	8	24
	Final Fit	15	8	25	48
	Multiple	91	55	43	189
	Skin Irritation	1	0	0	1
	Use of Prosthesis	22	34	9	65
Total		260	150	162	572

As observed in the table above, there were 125 client visits on fit issues within the normal body weight clients, 43 visits from those who were obese and 77 from overweight clients. Visits on consultation was low across, there were 6 consultation visits from normal body weight clients, 10 from obese and 8 from overweight clients. There were 15 normal body weights, 8 obese and 25 overweight client visits for final fit. Client visits for multiple issues (combination of any of the reasons for visit) were 91 from the normal body weights, 55 from obese and 43 from the overweight clients. There was only 1 visit on skin irritation from a normal body weight client. Client visits for use of prosthesis were 22 from normal body weights, 34 from obese and 9 from overweight clients. The figure below gives a graphical representation reason for visit and weight status.

Figure 28: Graph of Body Weight Status and Reason for Visit



Regression Analysis for Subset Working Age Group

A multiple linear regression analysis was carried out to estimate and identify correlations between these independent (predictor) variables and dependent variable in the acquired, congenital and total subset of working age clients. The legend for the dependent and predictor variables are as follows;

Table 28: Legend for Correlation in Working Age Subset Group

Legend	**Variable**
Total visit fitissue	Total number of visits for fit issues
Age	Age of client
Time lapse(mth) B4 prosfit	Time lapse in months before first prosthesis fitting
Distance from Fredericton	Distance travelled by clients for clinic visits
Avelength of visit	Average number of days spent per clinic visit for fit issues
Body weight status	Clients body weight status in relation to BMI

Regression Analysis for Subset of People with Acquired Amputations

Within the subset of people with acquired amputations there were 18 clients, 17 of them were valid and the remaining 1 was invalid (time lapse data missing). Body weight status was coded in SPSS as 1= "Underweight" (BMI <18.5 kg/m^2) 2= "Normal" (BMI ≥ 18.5 to <25.0 kg/m^2) 3= "Overweight" (BMI ≥ 25.0 to <30.0 kg/m^2) 4= "Obese" (BMI ≥ 30.0 kg/m^2).

Table 29: Descriptive Statistics for Acquired Subset Working Age Group

	Mean	Std. Deviation	N
Total Visit Fitissue	1.82	1.845	17
Age	49.71	15.818	17
Timelapse(mth) B4 Prosfit	10.47	7.666	17
Distance From Fredericton	160.88	148.895	17
Avelength of Days	1.12	.731	17
Body Weight Status	3.12	.781	17

Table 30: Correlations for Acquired Subset Working Age Group

		Total Visit Fitissue	Age	Timelapse(mth) B4 Prosfit	Distance From Fredericton	Avelength of Visit	Body Weight Status
Pearson Correlation	Total Visit Fitissue	1.000	-.285	-.113	-.073	.383	.059
	Age	-.285	1.000	.248	-.388	-.197	.195
	Timelapse(mth) B4 Prosfit	-.113	.248	1.000	.228	-.198	.376
	Distance From Fredericton	-.073	-.388	.228	1.000	-.130	.189
	Avelength of Visit	.383	-.197	-.198	-.130	1.000	.051
	Body Weight Status	.059	.195	.376	.189	.051	1.000
Sig. (1-tailed)	Total Visit Fitissue	.	.134	.333	.390	.065	.412
	Age	.134	.	.169	.062	.224	.226
	Timelapse(mth) B4 Prosfit	.333	.169	.	.190	.223	.068
	Distance From Fredericton	.390	.062	.190	.	.310	.234
	Avelength of Visit	.065	.224	.223	.310	.	.423
	Body Weight Status	.412	.226	.068	.234	.423	.

Within the subset of people with acquired amputations there was no strong correlation between the variables based on n=17 pairs. Table 30 above shows the correlations in the subset of people with acquired amputations.

Regression Analysis for Subset of People with Congenital Amputations

Within the subset of people with congenital amputations there were 16 clients, 14 of them were valid. The remaining 2 were invalid (time lapse data missing) the reason being that their first prosthesis fitting was not done at the Atlantic Clinic. The same coding for body weight status as shown above for the acquired clients was used in SPSS.

Table 31: Descriptive Statistics for Congenital Subset Working Age Group

	Mean	Std. Deviation	N
Total Visit Fitissue	7.29	5.810	14
Age	25.29	5.608	14
Timelapse(mth) B4 Prosfit	18.07	20.067	14
Distance From Fredericton	613.29	551.106	14
Avelength of Visit	2.11	1.350	14
Body Weight Status	2.57	.852	14

Within the subset of people with congenital amputations the correlation between distance from Fredericton and average number of days spent per visit is a positive relationship (0.650) based on the n=14 pairs of values. This means that as a congenital client distance from Fredericton increases the average number of days spent for each visit increases. The correlation is statistically significant at the 0.01 level (1-tailed) with a *p*-value of 0.006.

Table 32: Correlations for Congenital Subset Working Age Group

		Total Visit Fitissue	Age	Timelapse(mth) B4 Prosfit	Distance From Fredericton	Avelength of Visit	Body Weight Status
Pearson Correlation	Total Visit Fitissue	1.000	.451	-.159	-.349	-.198	-.238
	Age	.451	1.000	.266	-.340	-.195	.382
	Timelapse(mth) B4 Prosfit	-.159	.266	1.000	.014	-.053	.038
	Distance From Fredericton	-.349	-.340	.014	1.000	**.650**	-.071
	Avelength of Visit	-.198	-.195	-.053	.650	1.000	-.402
	Body Weight Status	-.238	.382	.038	-.071	-.402	1.000
Sig. (1-tailed)	Total Visit Fitissue	.	.053	.293	.111	.249	.207
	Age	.053	.	.179	.117	.252	.089
	Timelapse(mth) B4 Prosfit	.293	.179	.	.481	.428	.449
	Distance From Fredericton	.111	.117	.481	.	**.006**	.404
	Avelength of Visit	.249	.252	.428	.006	.	.077
	Body Weight Status	.207	.089	.449	.404	.077	.

Regression Analysis for the Total Subset Working Age Group

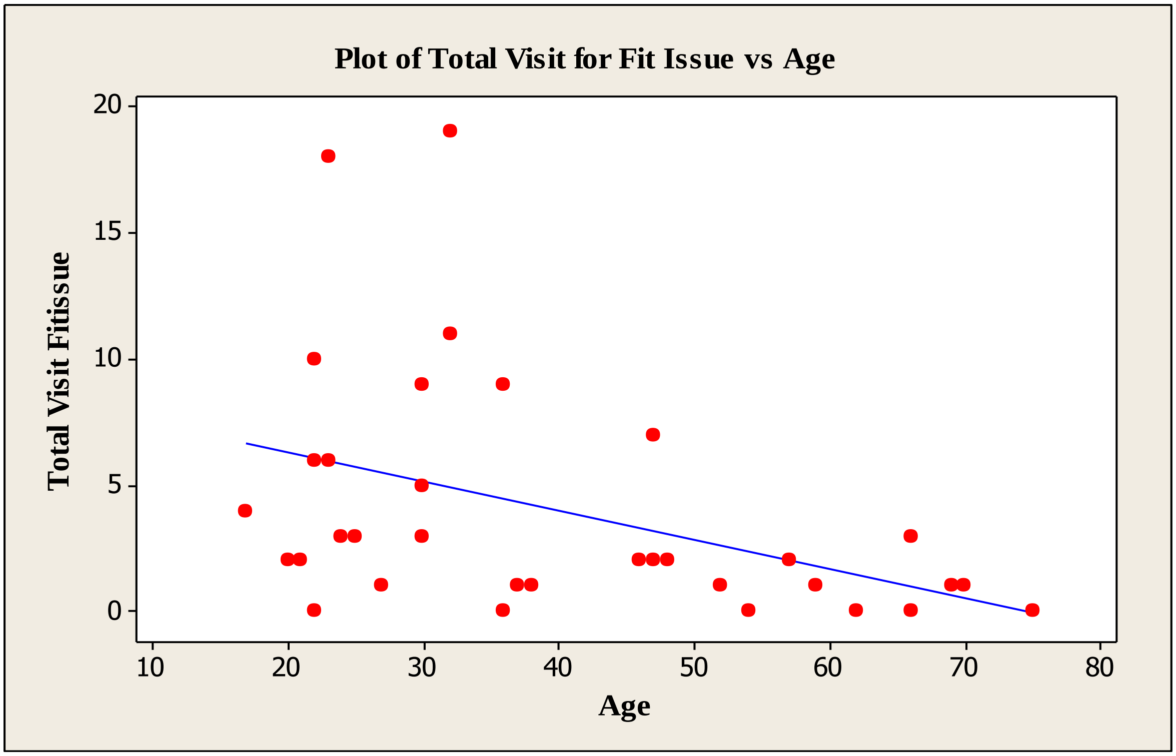
Within the total subset of working age clients there were 34 clients, of which 31 of them were valid and the remaining 3 invalid (time lapse data missing). The same coding for body weight status as shown above for the acquired clients was used in SPSS.

Table 33: Descriptive Statistics for the Total Subset Working Age Group

	Mean	Std. Deviation	N
Total Visit for Fit issue	4.29	4.907	31
Age	38.68	17.312	31
Time lapse(mth) B4 Prosfit	13.90	14.853	31
Distance From Fredericton	365.19	442.507	31
Avelength of Visit	1.57	1.153	31
Body weight Status	2.87	.846	31

From the total subset in table 34a, the correlation between age and total number of visits for fit issue is a negative relationship (-0.379) based on then=31 pairs of values. This means that as a client age increases the total number of visits for fit issues decreases and vice versa. In other words older clients visit the clinic less frequently for fit issues compared to younger clients. The correlation is statistically significant at the 0.01 level (1-tailed) with a *p*-value of 0.018. The figure below gives the graphical representation of the correlation between age and the total visit for fit issue.

Figure 29: Plot of Total Subset Age and Total Visit for Fit Issue



The correlation between distance from Fredericton and age is a negative relationship (-0.492) based on the n=31 pairs of values. Meaning younger clients travelled longer distances to the clinic than older clients. The correlation is statistically significant at the 0.01 level (1-tailed) with a *p*-value of 0.002.

Table 34a: Correlations for the Total Subset Working Age Group

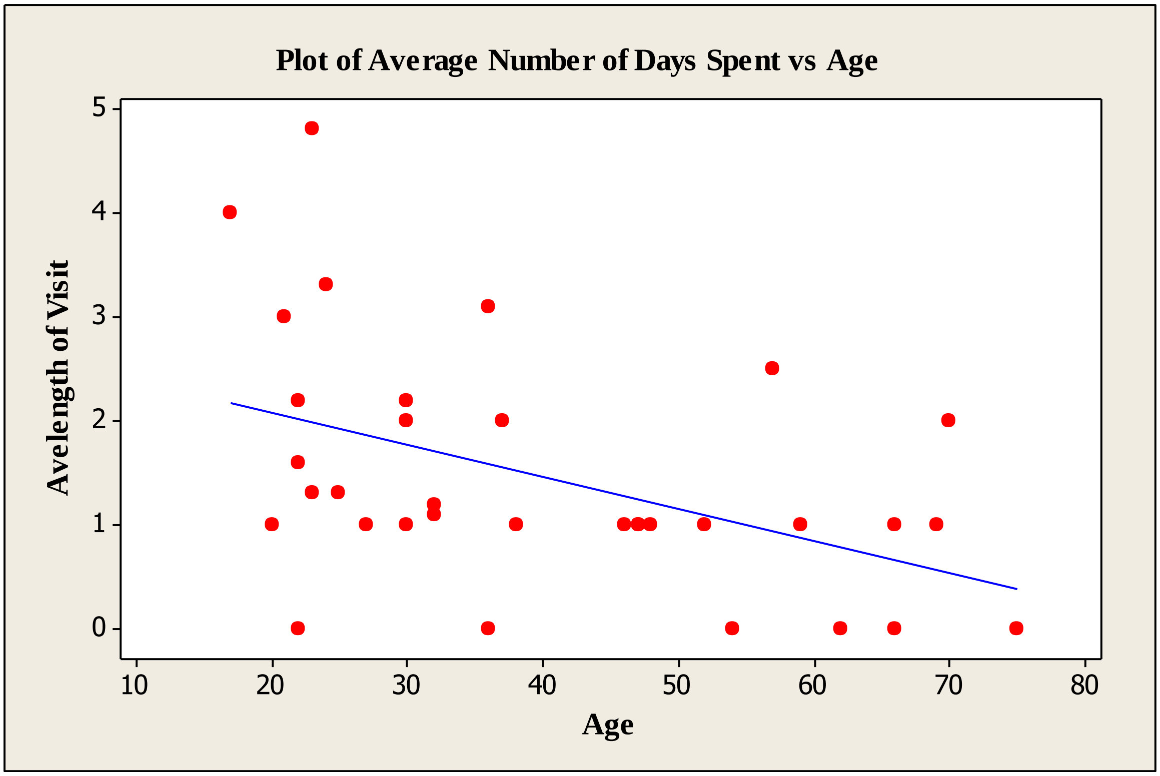
Correlations

		Total Visit for Fit issue	Age	Time lapse(mth) B4 Prosfit	Distance From Fredericton	Avelength of Visit	Body weight Status
Pearson Correlation	Total Visit for Fit issue	1.000	**-.379**	.024	.063	.176	-.296
	Age	-.379	1.000	-.072	**-.492**	**-.405**	**.375**
	Time lapse(mth) B4 Prosfit	.024	-.072	1.000	.165	.042	.033
	Distance From Fredericton	.063	-.492	.165	1.000	**.622**	-.176
	Avelength of Visit	.176	-.405	.042	.622	1.000	**-.332**
	Body weight Status	-.296	.375	.033	-.176	-.332	1.000
Sig. (1-tailed)	Total Visit for Fit issue	.	**.018**	.450	.368	.172	.053
	Age	.018	.	.350	**.002**	**.012**	**.019**
	Time lapse(mth) B4 Prosfit	.450	.350	.	.187	.411	.429
	Distance From Fredericton	.368	.002	.187	.	**.000**	.171
	Avelength of Visit	.172	.012	.411	.000	.	**.034**
	Body weight Status	.053	.019	.429	.171	.034	.

The correlation between age and average number of days spent per clinic visit is a negative relationship (-0.405) based on the n=31 pairs of values. This means that as a client age increases the average days spent per clinic visit decreases. In other words older clients spent fewer days per clinic visits compared to younger clients. The correlation is statistically significant at the 0.01 level (1-tailed) with a *p*-value of 0.012.

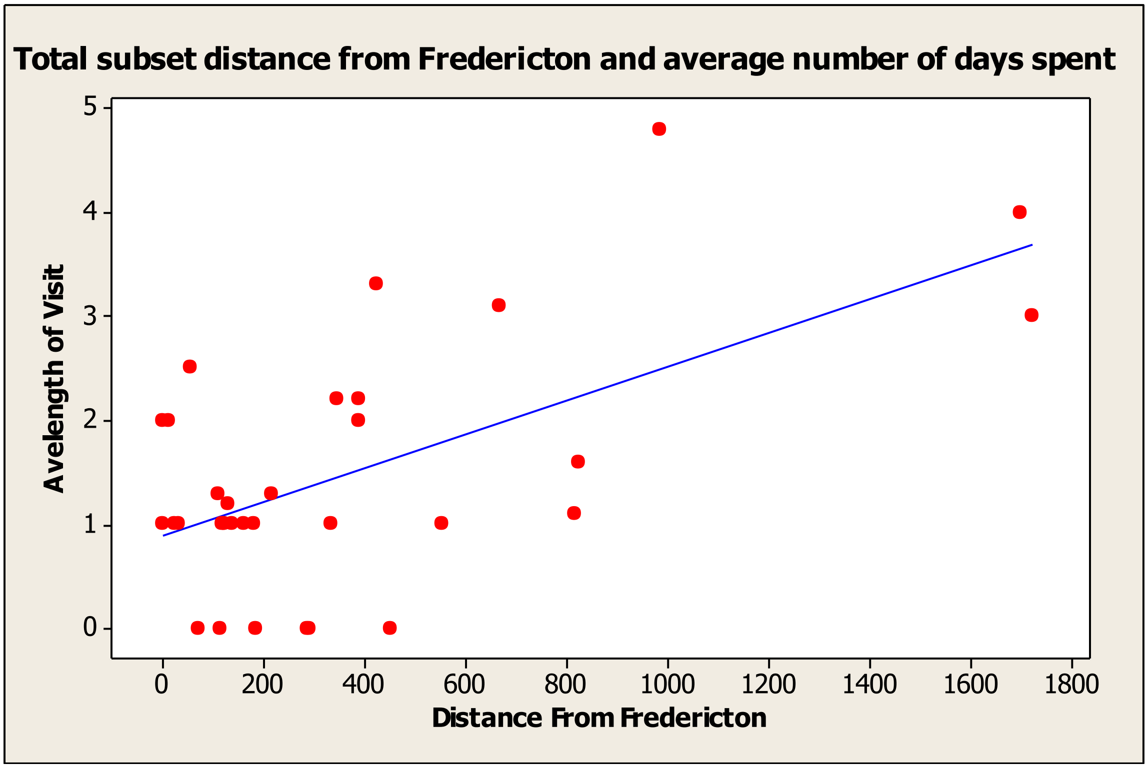
The figure below gives the graphical representation of the correlation between age and the average length of days spent per visit.

Figure 30: Plot of Total Subset Average Number of Days Spent and Age



The correlation between distance from Fredericton and average number of days spent per visit is a positive relationship (0.630) based on the n=31 pairs of values. This means that as a client distance from Fredericton increases the average days spent per visit also increases. The correlation is statistically significant at the 0.01 level (1-tailed) with a *p*-value of 0.000. The figure below gives the graphical representation of the correlation between subset distance from Fredericton and average number of days spent per clinic visit for fit issue.

Figure 31: Plot of Total Subset Distance from Fredericton and Average Number of Days Spent



The correlation between age and body weight status is a positive relationship (0.375) based on the n=31 pairs of values. This means that as a client age increases the body weight also increases. The correlation is statistically significant at the 0.01 level (1-tailed) with a *p*-value of 0.019.

The correlation between average number of days spent for each visit and body weight status in the working age subset population is a negative relationship (-0.332) based on the n=31 pairs of values. This means that as client body weight increases (and the client gets older) the average number of days spent for visits decreases. In other words clients who weighed more (older clients) spent fewer days per clinic visit. The correlation is statistically significant at the 0.01 level (1-tailed) with a *p*-value of 0.034.

Table 34b: Model Summary for the Total Subset

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.445[a]	.198	.038	4.814

a. Predictors: (Constant), Body weight Status, Time lapse(mth) B4 Prosfit, Distance From Fredericton, Age, Average days spent per Visit

From the model summary with an adjusted R^2 of 0.038, it means that only 3.8% of the total variability in total number of visits for fit issues is explained by the predictor (independent) variables.

Table 34c: ANOVA for the Total Subset predicting variation in dependent variable

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	143.057	5	28.611	1.235	.323[b]
	Residual	579.330	25	23.173		
	Total	722.387	30			

a. Dependent Variable: Total Visit for Fit issue
b. Predictors: (Constant), Body weight Status, Time lapse(mth) B4 Prosfit, Distance From Fredericton, Age, Average days spent per Visit

Chi-square values of $p = .323$ means the model is not statistically significant and this indicates that the model of predictor variables does not account for any significant variation in the total number of visits for fit issues.

Table 34d: Coefficients Table for Subset of Working Age Group

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.172	4.330		2.580	.016
	Age	-.109	.062	-.386	-1.765	.090
	Time lapse(mth) B4 Prosfit	.011	.060	.034	.187	.853
	Distance From Fredericton	-.003	.003	-.227	-.912	.370
	Average days spent per Visit	.458	1.021	.108	.449	.658
	Body weight Status	-.907	1.161	-.156	-.781	.442

a. Dependent Variable: Total Visit for Fit issue

Despite individual correlations being significant, the overall predictive power of the regression model was limited or not significant.

Discussion

Atlantic Clinic Demographic

From the results, the Atlantic Clinic for Upper Limb Prosthetics Fitting Centre had 212 client records. The clients were comprised of 37 children under the age of 18 years (17 males, 20 females), representing 17%. Adults made up 56% males (118 clients) and 27 % females (57 clients). In comparison to the study by Kyberd et al (1997), the Oxford Limb Fitting Centre had 341 clients record of which 197 were adult males (59%), 93 were adult females (28%) and 44 were children under 16 years (13%). On the other hand when the ages of children at the Atlantic Clinic for Upper Limb Prosthetics Fitting Centre were reduced to 16 years; they made up a total of 15% (31 clients). This leaves the adult population at 58% males (123 clients) and 27% females (58 clients). Overall, in terms of percentages the populations at Atlantic Clinic and Oxford Centre are similar but there is a difference of 129 in the sample size. However, the study by Wright et al. (1995) reported a much more male bias sample size such as 84% males and 16% females.

The unpaired t-test used to determine significance difference between the mean age in male and female clients showed that the Levene's test had an F-statistics of 5.647 with a significance value of 0.018. Since 0.018 < 0.05, the variables had a statistically different variance distributions. With a 2-tailed significance value 0.000 < 0.05, the difference between age means was 10.3 and this was statistically significantly higher for males. Hence mean age in female clients was 29.5 years and 39.8 in males confirming that the older population make up the majority of clients at the Atlantic clinic. In comparison to other studies, Pylatiuk et al. (2007) also reported a significant mean age difference in females (25.8) and males (35.6), indicating that majority of the study population were adults.

With regards to the level of limb loss or amputation, the results showed 21.5% partial hand, 5.6 % wrist disarticulation, 44.8% transradial, 1.1% elbow disarticulation, 19.3% transhumeral, 3.3 % shoulder disarticulation, 1.1% forequarter. What was unique in this study is that there were 2.2% other level of limb loss, 1.1% combination of partial hand/transradial and transradial/transhumaral whereas in other studies this was not reported. In other studies the level of loss was reported differently. For instance in the study by Wright et al. (1995) amputation levels were represented as 44% below elbow, 40% above elbow, and 16% shoulder disarticulations or forequarter amputations. Also the study by Dudkiewicz et al. (2004) reported level of loss as 71.41% above elbow, 9.52% trans-elbow, 11.93% below elbow and 7.14% Wrist. The table below gives a comparison of the percentage levels of loss (mostly reported on) between the Atlantic Clinic population and that of other surveys which is somehow different from the literature by Jain & Robinson (2008) and Watve et al, (2010).

Table 35: Level of Loss (excluding bilateral) Comparison to Other Studies

Level of Loss	**Jang, et al. (2011)**	**Burger and Marincek (1994)**	**Davidson (2002)**	**Watve et al. (2010)**	**Jain & Robinson (2008)**	**Atlantic Clinic**
Digits				27%	22%	
Partial Hand	17.9%	12.8%	6%	14%	19%	21.5%
Wrist Disarticulation	6.6%	3.7%	10%	1%	2%	5.5%
Transradial	48.4%	61.3%	31%	18%	19%	44.8%
Elbow Disarticulation	1.1%	0.8%		1%	0.3	1.1%
Transhumeral	19.4%	20.3%	23%	25%	28%	19.3%
Shoulder Disarticulation	6.6%	1.1%	10%		5%	3.3%
Forequarter			4%	4%	2%	1.1%

The variability in the amputation levels represented depends on the total population size as well as specific number of individual levels of loss. What is obvious across studies is that transradial is the most common level of loss. According to the WHO (2004) transradial is the most common and preferred level of amputation when no hand function can be expected, and it allows the highest level of functional recovery.

A one way ANOVA test on the level of loss in comparison to gender showed no significant difference (F = 0.003; *Sig*. = 0.958). Thus, irrespective of the gender, the mean level of loss in both males and females at the Atlantic Clinic was the same, that is, transradial. Also there was no significant difference (F = 0.588; *Sig*. = 0.444) in the types of loss. The mean level of loss in both congenital and acquired clients was the same, that is, transradial.

The type of loss represented in this study was categorized as congenital or acquired. From the results within the congenital group 62.7% were females and 37.3%

were males. The acquired group was highly dominated by 81.1% males with only 18.9% females. The male dominance in the acquired may be linked to work hazards, car accidents, etc. Also within the females there were more left sided loss 56.8% with 36.5% right side and 3.1% of both side. In the male population the left side was still fairly higher 50.4%, with 44.4% right and 5.1% both sides. The reason why left side of loss is slightly higher in this male population could be explained due the fact that there was quite a high number of congenital males 37.3% whilst only 18.9% females were acquired.

In the study by Kyberd et al. (1997), the cause of loss was also divided into the two categories of congenital and acquired. In their study, the male population was also dominated by acquired amputations, but more were right sided. Kyberd et al. observed a left side bias of the males with congenital losses in the study, which was similar to the study (McDonnell et al.,1988). They indicated that the left bias in the congenital losses was shown in the female population, although there were far fewer traumatic losses. Also a chi-square test for gender differences in the types of amputations $p = 0.000 < 0.05$ represented a highly statistically significant relationship between type of loss and gender in the Atlantic Clinic population. There were 37.3% congenital males compared to 81.1% acquired males. Also within the females 62.7% were congenital compare to 18.9% acquired. Likewise, Kyberd et al. (1997) found the larger number of females with a congenital loss in their study to be highly significant (< 0.005, Chi-squared) compared with the male population. However they indicated that the finding differed from other studies (McDonnell et al., 1988). The table below gives a comparison of the percentage side of loss between the Atlantic Clinic population and that of other surveys.

Table 36: Side of Loss Comparison to Other Studies

Side of Loss	**Kyberd & Hill (2011)**	**Jang, et al. (2011)**	**Østlie et al. (2011)**	**Atlantic Clinic**
Right	52%	45%	52.3%	41.4%
Left	47%	44%	47.7%	52.8%
Both		11%		5.8%
Unknown	1%			

Choice of Prosthesis, Cost and Coverage

The results on the choice of prosthesis showed that although most congenital clients were fitted with passive prosthesis initially, they later switched to myoelectric prosthesis. In the acquired population the frequent choice throughout was myoelectric prosthesis. However what was common is that in both acquired and congenital clients most of them had more than one type of prosthesis, preferable myoelectric and passive. Kyberd et al, (1998) indicated that many subjects in their study were users of more than one type of prosthesis, including purely cosmetic hands, split hooks, and devices that had a cosmetic appearance but with a designed functional range (such as myoelectric hands). In the Gaine et al, (1997) study 13 of the traumatic amputees had more than one type of prosthesis. Both the cosmetic and myoelectric prostheses were favoured. Also Gaine et al, (1997) indicated that in their traumatic group (n =23), preference of prosthesis were myoelectric prosthesis 9, cable-assisted body powered 7, and cosmetic prosthesis 7. Within the congenital group (n =27), preference of prosthesis were myoelectric 16, cable-assisted body powered 1, and cosmetic prosthesis 9. The similarity in the Atlantic Clinic study and that of Gaine et al, is that body powered prosthesis was not a highly preferred choice for most clients (only used by a few clients). Martin &

Edeer (2011) indicated that amputees will require more than one type of prosthesis and therefore they should be offered a variety to choose from.

Cost of prosthesis over the years has increased significantly due to economic inflations, downturn, and technological advancement in prosthesis components and materials. The cost of prostheses is also dependent on factors such as the level of the amputation, type of components used and degree of functionality. In the entire clinic history the highest cost of prosthesis was $99,109. The study by Resnik et al, (2012) indicated that a body powered upper limb prosthesis costs approximately $7000. Myoelectrically controlled devices that use 1 of the advanced hands that have recently been introduced to the market, such as the BeBionic hand or the I-Limb Pulse, cost $40,000 to $50,000. However an above-the-elbow, myoelectrically controlled prosthesis may cost nearly $100,000, more than twice the cost of a body-powered, above-the-elbow device and the cost of prosthesis at the Atlantic Clinic from 2009 to 2012 gave a perfect reflection of that.

According to Resnik et al, (2012) cost can be a barrier to successful prosthetic use when there are insufficient financial sources for maintenance, repair, and replacement, or a need for multiple devices to effectively perform different tasks. Blough et al, (2010) reported that lifetime prosthetic costs ranged from $103,442 to more than $877,039 for unilateral upper limb amputees, and $227,874 to more than $1,992,782 for bilateral upper limb amputees.

For many amputees, the coverage restrictions of third-party payers impact prosthetic rehabilitation. In Canada upper limb prosthesis like all other assistive products are not covered under the *Canada Health Act*.

The results from the Atlantic Clinic showed that the cost of prosthesis for majority of the clients were covered by War Amps, followed by insurance, government, worker's compensation and then out of pockets. War Amps covered full cost (including travel and accommodation) for younger clients so they were able to travel longer distance to the Atlantic Clinic. The coverage's under the government were mostly provided by Medical Services Insurance (MSI) for clients from Nova Scotia and a few by Social Development New Brunswick. MSI covered some of the cost of prostheses (but not the full cost) whilst the province of NB only covered a passive prosthesis for clients on social assistance (welfare). The worker's compensation boards in all Atlantic Provinces covered full cost of prostheses based on the policy that the need for the prosthesis should be the result of a compensable work injury and should be recommended by an approved health care provider. Most of the older clients who travelled longer distance to the Atlantic were covered by worker's compensation.

Subset of Working Age Group

The results on the subset of working age population showed that the acquired clients were mostly older adults. The mean age for acquired amputees was 49.7 years whilst the mean age at amputation was 51.1 years. The average time lapse from acquired amputation to first prosthesis fitting was 10.5 months and this varied from 2 to 33 months. In comparison to the study of a working age group by Gaine et al, (1997), the average time from traumatic amputation to initial fitting of prosthesis was 6.5 months and this varied from 8 weeks to 2 years. In the Gaine et al. study, average age of the traumatic amputees was 37 years whilst the average age at amputation was 28 years. Surprisingly, the congenital clients within the subset of working age population had a slightly higher average time lapse from amputation to first fitting (18.1 months) with the mean age being 25.3 years.

In results of the subset of working age clients, 38.2% were of normal body weight, 32.4% were overweight and the remaining 29.4% were obese. What this means is that 61.8% of the clients had BMI above the overweight border line, and the majority being acquired amputees. On the other hand, most of the congenital clients were of normal body weight status. Pavlou (2008) indicated that amputees with high BMI face an additional set of issues that do not affect amputees in the normal weight range. Although overweight issues affect lower limb amputees more than upper limb amputees because of the obvious weight bearing issues that arise when fitting lower limb prostheses, prosthetists may be challenged with finding myoelectric sites, determining the best socket design and resolving harnessing issues for upper limb overweight amputees.

It is more difficult to fit a prosthesis on a limb with an excess of soft tissue. The prosthesis interface locks onto the bones in the residual limb, but extra soft tissue makes that difficult, or impossible. High BMI in amputees also affects issues like oedema and volume changes, making them more prevalent (Pavlou, 2008). The build-up of fluids in the limb (oedema) can make prosthetic devices fit improperly and contribute to skin problems (Handbook of Disabilities, 2001). Individuals experiencing the amputation of a limb or limbs may also have more difficulty with weight control because of the reduced body mass and exercising the main component to reversing excess weight becomes even harder and less likely when an amputee is overweight or obese (Pavlou, 2008).

The results of the subset working age clients also showed that fit issues, skin irritation, multiple issues (function, component, repairs) were highest in normal body weight clients who were fairly young adults. Although the literature ((Pavlou, 2008; Handbook of Disabilities, 2001) suggest that this is more prevalent in overweight amputees, some studies (Kyberd & Hill, 2011; Biddas & Chau, 2007) have also indicated that they are more prevalent in frequent prosthesis wearers. In the study by Kyberd & Hill (2011), majority of respondents who were long-term prosthesis wearers reported frequent problems as fit issues, function and maintenance. Also in the study by Biddas & Chau (2007), skin irritations were more prevalent in frequent wearers than in prosthesis rejecters.

This result could not prove the hypothesis that body overweight leads to longer delays before first prosthesis fitting and fit issues for amputees. The congenital group mostly made up of normal body weight clients recorded the highest fit issues indicating that there are a lot more contributing factors to fit issues than just body overweight.

Obesity in the Atlantic Canada General Population

As a major contributor to preventive death in Canada today, overweight and obesity pose a major public health challenge. Unfortunately data for comparison on the health status of amputee populations were not available. Although the sample size of the Atlantic Clinic subset of working age group was very small, 29.4% of the clients were obese. In comparison, the prevalence of self-reported adult obesity from the general population in 2003, 2005, and 2007are; for Canada (15.4%, 15.8%, and 17.1%, respectively), New Brunswick (20.7%, 23.1%, 21.2%), Nova Scotia (20.6%, 21.3%, 20.9%), Prince Edward Island (21.5%, 23.0%, 23.1%), and Newfoundland and Labrador (20.6%, 24.5%, 23.4%) (PHAC, 2009). There was an increase in the obesity rate across all 4 Atlantic Provinces and in Canada from 2003 to 2007. The increase rate was highest for the Atlantic Provinces in 2005 and Canada was highest in 2007. The higher rate of obesity among the subset of working age amputees is suggestive of increased risk among these individuals.

Approximately one in four Canadian adults are obese, according to measured height and weight data from 2007-2009 (Statistics Canada). Between 1981 and 2007/09, obesity rates roughly doubled among both males and females in most age groups in the adult and youth categories. Current data from Statistics Canada estimates that the total populations of overweight and obese adults from 18years and above have increased from 12.1 million in 2007 to 13.2 million in 2011.

The economic costs of obesity were estimated at $4.6 billion in 2008, up about 19% from $3.9 billion in 2000, based on costs associated with the eight chronic diseases most consistently linked to obesity (PHAC, 2011b). Estimates rose to close to $7.1 billion when based on the costs associated with 18 chronic diseases linked to obesity. From 1985 to 2000, 57,000 deaths in Canada were associated with overweight and obesity (Katzmarzyk & Ardern, 2004).

Health Implication of Overweight and Obesity

Amputees who fail to accurately identify their overweight status are more likely to suffer from obesity related diseases. An in-depth knowledge of obesity, factors that influence it and risk for related diseases can help in combating obesity by encouraging healthy behaviours and lifestyle thus reducing costs associated with obesity related diseases whiles promoting longevity. Some common health consequences of obesity and overweight are cardiovascular diseases (mainly heart disease and stroke), which were the leading cause of death in 2008 (WHO), diabetes and musculoskeletal disorders (especially osteoarthritis - a highly disabling degenerative disease of the joints). Other medical conditions are some cancers (endometrial, breast, and colon), breathing disorders (sleep apnea and chronic obstructive pulmonary disease), depression, gallbladder or liver disease, gastro-esophageal reflux disease (GERD), high blood pressure and high cholesterol.

Obesity and Cardiovascular Disease

Obesity is a major contributor to the risk of cardiovascular disease also known as coronary heart disease (CHD). As the body mass index rises, so does the risk for coronary heart disease. CHD is a condition in which a waxy substance called plaque builds up inside the coronary arteries (National Heart Lung and Blood Institute). These arteries supply oxygen-rich blood to the heart. Plaque can narrow or block the coronary arteries and reduce blood flow to the heart muscle. This can cause angina or a heart attack. Obesity can also lead to heart failure. This is a serious condition in which the heart is not able to pump enough blood to meet the body's needs (National Heart Lung and Blood Institute).

In the Framingham Heart Study, the 26-year incidence of coronary heart disease (CHD) was increased by a factor of 2.4 in obese women and 2 in obese men under age of 50 years (Hubert et al., 1983). Excess weight was an independent predictor of coronary artery disease, coronary death and congestive heart failure after adjusting for other known recognized risk factors. In the Nurses' Health Study from the United States, the risk of developing CHD increased 3.3-fold with BMI > 29 kg/m^2 and 1.8-fold between 25 and 29 kg/m^2 , compared to those women with BMI < 21 kg/m^2 (Manson et al., 1990, 1995). Each kilogram of weight gained from the age of 18 years was associated with 3.1% higher risk of cardiovascular disease (Willett et al., 1995). The increased CHD risk is better correlated with abdominal or central obesity than simple BMI (Rich-Edwards et al., 1995). In the Nurses' Health Study, a waist– hip ratio (WHR) of $\geq$0.88 versus WHR < 0.72 was associated with an increased relative risk of CHD of 3.25 (Rexrode et al., 1998).

The Heart and Stroke Foundation current statistics on heart disease and stroke in Canada, as well as their related risk factors indicates that since 1952 the cardiovascular death rate in Canada has declined by more than 75% and nearly 40% in the last decade. This is largely attributed to research advances in surgical procedures, drug therapies and prevention efforts (Statistics Canada, 2011c).

Statistics Canada indicates that every 7 minutes in Canada, someone dies from heart disease or stroke. In 2008 cardiovascular disease accounted for 29% of all deaths in Canada (69,703 deaths or more than 69,500), 28% of all male deaths, and 29.7% of all female deaths (Statistics Canada, 2011c). Heart disease and stroke costs the Canadian economy more than $20.9 billion every year in physician services, hospital costs, lost wages and decreased productivity (Conference Board of Canada, 2010). In 2007, 1.3 million Canadians representing 4.8% of total population (4.2% of girls and women and 5.3% of boys and men 12 years of age and older) reported having heart disease (PHAC, 2009).

Obesity and Type 2 Diabetes

Obesity is a powerful risk factor for the development of type 2 diabetes and more than two-thirds of patients with type 2 diabetes are obese. The risk of type 2 diabetes correlates positively with increasing obesity (Larsson et al., 1981; Harris, 1989). In the

Nurses' Health Study, the risk of developing diabetes increased five-fold in women with BMI of 25 kg/m^2 compared with those with BMI of 22 kg/m^2. The risk becomes higher reaching 28-fold with BMI of 30 kg/m^2 and 93-fold with BMI > 35 kg/m^2 (Colditz et al., 1990). The risk of obesity and type 2 diabetes was better defined by a high waist to hip ratio and waist circumference (Larsson et al., 1984). Also, the risk of type 2 diabetes from obesity is more prevalent across certain ethnic groups such as South Asians and Afro-Caribbeans (Bhopal, 2002).

According to the National Diabetes Surveillance System (2005), 6.6% of the population age 20 and over, have been diagnosed with diabetes (PHAC, 2009). An estimated 2.5 million Canadians have been diagnosed with diabetes in 2010. From 2010 to 2020, another 1.2 million people are expected to be diagnosed with diabetes, bringing the total to about 3.7 million (Canadian Diabetes Association, 2009).

It is estimated that 90 to 95% of Canadians with diabetes have type 2 diabetes, while 5 to 10% have type 1 diabetes (PHAC, 2011a). The economic burden of diabetes in Canada is expected to be about $12.2 billion in 2010, measured in inflation adjusted 2005 dollars. The cost of the disease is expected to rise to $17 billion by 2020 (Canadian Diabetes Association, 2009).

Obesity and Hypertension

A rise in blood pressure is associated with increased body weight. Epidemiological studies indicate that obesity is a strong independent risk factor for hypertension (Modan et al., 1985; Stamler et al., 1993). In the Framingham Study, for example, the prevalence of hypertension among obese individuals was twice that of those individuals with normal weight irrespective of sex and age (Hubert et al., 1983). In the Nurses' Health Study, the relative risk of hypertension in those women who gained 5.0 to 9.9 kg and greater than 25.0 kg was 1.7 and 5.2, respectively (Huang et al., 1998). The risk of hypertension was even higher with abdominal obesity (WHR 0.9 in men and ≥ 0.85 in women) (Blair et al., 1984).

According to Wilkins et al. (2010), 6 million Canadian adults or one in five, have high blood pressure, representing 19% of the adult population. Also, 1 in 5 Canadian adults (20%) have blood pressure readings in the high normal range and are considered pre-hypertensive. Amongst Canadians with high blood pressure; 83% are aware of their condition (80% for men and 87% for women), 17% are unaware of their condition (20% for men and 14% for women), 80% have it treated (77% for men and 83% for women), 66% have it treated and under control (67% for men and 65% for women).

The Canadian Health Measures Survey (CHMS) indicates that 19.0% of Canadian females aged 29 to 79 years have high blood pressure; 19.7% of Canadian men aged 20 to 79 years have high blood pressure; 18.4% of Canadians aged 40-to 59 years have high blood pressure; and 53.2% of Canadians aged 60 to 79 years have high blood pressure (Wilkins et al, 2010). Among Canadian children and youth, 3.7% have a measured blood pressure that is considered borderline or elevated. Blood pressure is generally higher among overweight and obese children and youth (Roberts et al., 2012).

Part of the development of this work has involved guidelines for estimating BMI and its associated health risk in upper limb amputee population which are shown in appendix D.

Conclusion and Recommendation

The Atlantic Clinic client population corresponds to similar trends from studies in other upper limb prosthetic clinics around the world. The majority of clients are men with acquired transradial loss. Within clients with congenital loss, females (both amongst adults and children) make up the larger group. However, contrary to other studies, left side of loss is highest in both male and female. The percentage corresponding to amputation levels is similar to most but not all studies.

This study has shown that as clients get older at the clinic (from children to adults) their total number of visits for fit issues decreases, in other words adult clients visit less frequently. Also younger clients mostly people with congenital amputations travelled longer distance (NS, NFLD and PEI) to the Atlantic Clinic and they spent more days to get all issues resolved.

This study also showed that a high proportion (77.8%) of the acquired clinic subset population have BMIs above the overweight border-line. However due to the low statistical power (small sample size), and because BMI is one among many factors, it is difficult to conclude that acquired amputees have more difficulty in controlling their body weight than those with congenital limb loss. In this study it was shown that body overweight alone does not lead to longer delays before first prosthesis fitting and fit issues for acquired amputees. Longer delays before first prosthesis fitting is also influenced by factors such as complications that arise after amputation, delayed wound healing, lack of funding source for prosthesis, and accessibility of the nearest prosthesis fitting center. Fit issues on the other hand may be as result of frequent wearing of prosthesis as well.

The results also indicated that the preferred choice of prosthetic devices by most clients was myoelectric, and then passive, or a combination of both with others. This result supports evidence that the myoelectric prosthesis has become one of the preferred prosthetic devices and may be a cost effective choice since it provides greater comfort, more range of motion, larger functional area, and a more natural appearance. However, currently the high cost barrier makes the use of a myoelectric prosthetic impossible for some amputees without prosthesis coverage (out of pocket amputees).

Recommendation for the Clinic Team

There is no doubt that upper limb amputation, as the result of trauma, disease or congenital malformation, is a problem that will lead to a certain level of functional disability and the use of prosthetic may increase the functional capacity of persons with a missing upper limb. The rehabilitation process can be both physically and emotionally challenging and for most acquired amputees' body weight management also becomes difficult. Since the Atlantic Clinic is only a prosthesis fitting centre, the clinic team should support clients, particularly with regard to information provision, to ensure clients are receiving psychological, emotional, and nutritional advice as well as on activity levels that will not put strain on their good arm since most amputees do very well with the aid of a well-coordinated multidisciplinary team.

Suggestions for Future Research

This study focused on a broad description of the Atlantic clinic. The sample size and the broad nature of variables under study make it difficult to draw specific conclusions about the clinic and its clients. It was clear that cost per specific prosthesis device and components were not distinguishable thus making it difficult to compare cost per specific prosthesis device and component. Future study, narrowed down on cost would provide more details on the cost per prosthetic device and component. Also a high proportion of the acquired clients have BMIs above overweight. A future study employing other anthropometric measuring variables such as waist to hip ratio and waist circumference would give a better indication of risk for obesity related diseases (cardiovascular disease, type 2 diabetes and hypertension). A qualitative study to assess whether clients are receiving psychological and nutritional advice would help the clinic team identify gaps in case a multidisciplinary team is not involved in the rehabilitation process since prosthesis fitting and training only forms one part of the rehabilitation process.

References

Aleccia J. (March, 2010). Limb loss a grim, growing global crisis. Retrieved from the website; http://haitiamputees.msnbc.msn.com/_news/2010/03/19/4040341-limb-loss-a-grim-growing-global-crisis

Amputee Coalition of Canada. Defining Canadian Statistics on Limb Loss Incidence and Prevalence. http://www.amputeecoalitioncanada.org/pg_ResourceCARALimbLoss.php

Atkins, D. (2002). Adult upper limb prosthetic training. In Bowker, H. K. & Michael J. W. (Eds.), Atlas of Limb Prosthetics: Surgical, Prosthetic, and Rehabilitation Principles. Rosemont, IL. *American Academy of Orthopedic Surgeons*, 2nd Edition.

Bannerman, E., Thomas, J. & Miller, M. (2012). Nutritional anthropometry for amputees: Challenges for clinicians. In Preedy, V. R. (Ed.), Handbook of Anthropometry: Physical Measures of Human Form in Health and Disease. DOI: 10.1007/978-1-4419-1788-1. pp2745-54

Bhaskaranand, K., Bhat, A. K, & Acharya, K. N. (September, 2003). Prosthetic rehabilitation in traumatic upper limb amputees (an Indian perspective). *Archives of Orthopaedic and Trauma Surgery*. *123*(7):363-6.

Bhopal, R. (2002). Epidemic of cardiovascular disease in South Asians. *British Medical Journal*. 324:625-6

Biddiss, E. & Chau, T. (December, 2007). Upper-limb prosthetics: critical factors in device abandonment. *American Journal of Physical Medicine and Rehabilitation*: 86(12):977-87.

Biddiss, E. A. & Chau, T. T. (September, 2007). Upper limb prosthesis use and abandonment: a survey of the last 25 years. *Prosthetics and Orthotics International*. *31*(3):236-57.

Blair, D., Habicht, J. P., Sims, E. A., Sylwester, D., & Abraham, S. (1984). Evidence for increased risk for hypertension with centrally located body fat and the effect of race and sex. *American Journal of Epidemiology*. *Volume 119*. Issue 4:526– 40.

Blough, D. K, Hubbard, S., McFarland, L.V., Smith, D.G., Gambel, J. M., & Reiber, G. E. (2010). Prosthetic cost projections for service members with major limb loss from Vietnam and OIF/OEF. Journal of Rehabilitation Research and Development. *47*(4):387-402.

Bone structure of human arm (Wikimedia Commons Contributors, 2008) http://en.wikipedia.org/wiki/File:Human_arm_bones_diagram.svg

Bouwsema, H., van der Sluis C. K., & Bongers, R. M. (2010). Learning to control opening and closing a myoelectric hand. *Archives of Physical Medicine and Rehabilitation.* 91:1442-6.

Burger, H. & Marinček Č. (2007). Return to work after lower limb amputation. *Disability and Rehabilitation. 29*(17):1323 –1329

Canadian Diabetes Association. (December, 2009). An economic tsunami the cost of diabetes in Canada. Retrieved from: http://www.diabetes.ca/documents/get-involved/FINAL_Economic_Report.pdf

Capital Health of Nova Scotia. Amputee Rehabilitation, Musculoskeletal Program: Upper limb amputation. Retrieved from website; http://www.cdha.nshealth.ca/amputee-rehabilitation-musculoskeletal-program/upper-limb-amputation

Capital Health of Nova Scotia. Handbook of Information for People with Amputations of the Upper Limbs. Queen Elizabeth II Health Sciences Centre: Nova Scotia Rehabilitation Centre. Retrieved from website; http://www.cdha.nshealth.ca/patientinformation/nshealthnet/0648.pdf

Chan, A.Y. K. **(**October, 2012). Assessment of upper limb myoelectric prostheses. The University of British Columbia. Retrieved from website; https://circle.ubc.ca/bitstream/.../ubc_**2012**_fall_**chan**_anthony.pdf?...1

Colditz, G. A., Willett, W. C., Stampfer, M. J., Manson, J. E., Hennekens C. H., Arky, R. A., & Speizer, F. E. (1990). Weight as a risk factor for clinical diabetes in women. *American Journal of Epidemiology*. *Volume 132*. Issue 3:501–13.

Conference Board of Canada. (February, 2010). The Canadian Heart Health Strategy: Risk Factors and Future Cost Implications Report.

Craig, C. K. (2011). Estimating joint loads in normally limbed children and Children using upper limb prostheses.

Davidson, J. (Jan-Mar, 2002). A survey of the satisfaction of upper limb amputees with their prostheses, their lifestyles, and their abilities. *Journal of Hand Therapy*. *15*(1):62-70.

Davidson, J. H., Jones, L. E., Cornet, J. & Cittarelli, T. (2002) Rehabilitation in Practice: Management of the multiple limb amputee. *Disability and Rehabilitation. 24*(13):688-99

De Godoy, J. M. P., Braile, D. M., Buzatto, S. H. G., Longo, O., & Fontes, O. A. (2004). Quality of life after amputation. *Journal of Psychology, Health & Medicine: Volume* 7; No. 4.

Dickhaut, S.C., DeLee, J. C., & Page, C. P. (Jan 01, 1984). Nutritional status: importance in predicting wound-healing after amputation. *Journal of Bone and Joint Surgery, American.* 66(1):71-75

Dillingham, T. R., Pezzin, L. E., & MacKenzie, E. J. (August 2002). "Limb Amputation and Limb Deficiency: Epidemiology and Recent Trends in the United States," *Southern Medical Journal. 95*(8): 875-83.

Dudkiewicz, I., Gabrielov, R., Seiv-Ner, I., Zelig, G., & Heim, M. (2004). Evaluation of prosthetic usage in upper limb amputees. *Journal of Disability and Rehabilitation* 26(1): 60–63

Eneroth, M. (December, 1999). Factors affecting *wound healing after* major *amputation* for vascular disease: a review. *Prosthetics and Orthotics International. 23(3)*:195-208.

Escott-Stump, S. (2008). *Nutrition and Diagnosis-Related Care*. 6th Edition. Philadelphia, PA: Williams & Wilkins Inc.

Esquenazi, A. & DiGiacomo R. (January, 2001). Rehabilitation after Amputation. *Journal of the American Podiatric Medical Association. Volume 91*(1). Retrieved from website; http://analisedemarcha.com/papers/o_p/Rehabilitation%20After%20Amputation.pdf

Freeland, A. E, & Psonak, R. (2007). Traumatic below-elbow amputations. *Journal of Orthopedics. 30*(2):120-6.

Flannery, C. J & Faria, H. S. (1999). Limb Loss: Alterations in body image. *Journal of Vascular Nursing. 17*(4):100-106.

Gaine, W.J., Smart, C. & Bransby-Zachary, M. (1997). Upper Limb Traumatic Amputees: Review of prosthetic use. *Journal of Hand Surgery (British and European Volume)* 22:73

Gitter, A. & Bosker, G. (2005). Upper and Lower Extremity Prosthetics. 4th Edition, *Volume* II. Philadelphia: Lippincott-Raven

Handbook of Disabilities. (2001). Amputation. University of Missouri. Retrieved from website; http://dps.missouri.edu/resources/Handbook/amputation.pdf

Harris, M. I. (1989). Impaired glucose tolerance in the US population. Diabetes Care 12:464.

Heart and Stroke Foundation. Current statistics on heart disease and stroke in Canada, and their related risk factors. Retrieved from the website; http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.3483991/k.34A8/Statistics.htm

Horgan, O. & Maclachlan, M. (2004). Disability and Rehabilitation: Psychosocial adjustment to lower-limb amputation. 26 (14/15):837-850.

Huang, Z., Willett, W. C., Manson J. E., Rosner, B., Stampfer, M. J., Speizer, F. E., Colditz, G. A. (1998). Body weight, weight change and risk for hypertension in women. *Annals of Internal Medicine*.128:81–88

Hubert, H.B., Feinleib, M., McNamara, P. M. & Castelli, W. P. (1983). Obesity as an independent risk factor for cardiovascular disease: a 26 year follow-up of participants in the Framingham Heart Study. Circulation 67:968–77.

Incledon, L. (2004). *Strength Training for Women.* Champaign, Illinois: Human Kinetics Publishers.

Jain, A. S. & Robinson, D. P. H. (September, 2008). Synopsis of Causation; Upper Limb Amputation. Retrieved from website; http://www.veterans-uk.info/publications/amputation_upper_limb.pdf

Jang, C. H., Yang, H. S., Yang, H. E, Lee, S. Y., Kwon, J. W., Yun, B. D., …. & Jeong, H. W. (2011). A Survey on Activities of Daily Living and Occupations of Upper Extremity Amputees. *Annals of Rehabilitation Medicine.* 35: 907-921.

Jones, L. E. & Davidson, J. (1996). A review of the management of upper-limb amputees. *Critical Reviews in Physical Rehabilitation Medicine. 8*(4):297-322.

Katzmarzyk, P. T., & Ardern, C. I. (2004). Overweight and obesity mortality trends in Canada 1985-2000. *Canadian Journal of Public Health. 95*(1):16-20.

Kejlaa, G. H. (1992). The social and economic outcome after upper limb amputation. *Prosthetics and Orthotics International.16:*25-31.

Kelly, B. M. (August, 2013). Upper Limb Prosthetics: *Overview. eMedicine Physical Medicine and Rehabilitation*. Retrieved from website; http://emedicine.medscape.com/article/317234-overview#aw2aab6b3

Kyberd, P. J., Beard D. J., & Morrison J. D. (1997). The population of users of upper limb prostheses attending the Oxford Limb Fitting Service. *Prosthetics and Orthotics International. 21*:85-91

Kyberd, P J., Davey, J. J., & Dougall Morrison, J. (1998). A Survey of Upper-Limb Prosthesis Users in Oxfordshire. *10*(4): 85-91 http://www.oandp.org/jpo/library/1998_04_085.asp

Kyberd, P. J. & Hill, W. (2011). Survey of upper limb prosthesis users in Sweden, the United Kingdom and Canada. *Prosthetics and Orthotics International*. *35*(2) 234–241

Lake, C. & Dodson, R. (February, 2006). Progressive upper limb prosthetics. *Physical Medicine and Rehabilitation Clinics of North America. 17*(1):49-72.

Larsson, B., Bjorntorp, P. & Tibblin, G. (1981.) The health consequences of obesity. *International Journal of Obesity*. 5:97– 116.

Larsson, B., Svardsudd, K., Welin, L., Wilhelmsen, L., Bjorntorp, P., Tibblin, G. (1984). Abdominal adipose tissue distribution, obesity, and risk of cardiovascular disease and death: 13 year follow up of participants in the study of men born in 1913. *British Medical Journal* (Clin Res Ed). 288:1401– 4.

LeBlanc, M. (December, 1988). Use of prosthetic prehensors. *Prosthetics and Orthotics International.* 12(3):152-4.

Magermans, D. J., Chadwick, E. K., Veeger, H. E., & van der Helm, F.C. (July 2005). Requirements for upper extremity motions during activities of daily living. *Clinical Biomechanics (Bristol, Avon),* 20(6):591-9

Maguire, P. (April 4, 1998). Surgery and loss of body parts. *British Medical Journal. 316:*1086–8

Mahan L. K., Escott-Stump, S., & Raymond, J. L (2012). Krause's Food and the Nutrition Care Process. Elsevier Saunders. 13th Edition. p1066

Manson, J. E., Colditz, G. A., Stampfer, M. J., Willett, W. C., Rosner, B., Monson, R. R., Speizer, F. E., & Hennekens, C.H. (1990). A prospective study of obesity and risk of coronary heart disease in women. *New England Journal of Medicine*. 322, 882–889

Manson, J. E., Willett, W. C., Stampfer, M..J., Colditz, G. A., Hunter, D. J., Hankinson, S. E., …. & Speizer, F. E. (1995). Body weight and mortality among women. *New England Journal of Medicine.* 333:677–85.

Martin, C. W. & Edeer, D. (February, 2011). Upper Limb Prostheses: A Review of the Literature with a Focus on Myoelectric Hands. *Clinical Services – Worker and Employer Services, WorkSafe BC*. Retrieved from the website; http://www.worksafebc.com/health_care_providers/Assets/PDF/UpperLimbProstheses.pdf

McDonnell, P. M., Scott, R. N., & McKay, A. (1988). Incidence of Congenital Upper-Limb Deficiencies. *Journal of the Association of Children's Prosthetic & Orthotic Clinics. 8-10.*

Modan, M., Halkin, H., Almog, S., Lusky, A., Eshkol, A., Shefi, M., …. & Fuchs, Z. (1985). Hyperinsulinemia: a link between hypertension, obesity and glucose intolerance. *The Journal of Clinical Investigation*. 75:809–817,

Modan, M., Peles, E., Halkin, H., Nitzan, H., Azaria, M., Gitel, S., Dolfin, D., & Modan, B. (November 15, 1998). Increased cardiovascular disease mortality rates in traumatic lower limb amputees. *American Journal of Cardiology*. 82(10):1242-7.

Mozumdar, A., & Roy, S. K. (2004). Method for estimating body weight in persons with lower-limb amputation and its implication for their nutritional assessment. *American Journal of Clinical Nutrition*. *80*:868-75

National Health and Nutrition Examination Survey: (January, 2007). Anthropometry Procedures Manual. Retrieved from website; http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf

National Heart Lung and Blood Institute. What Are the Health Risks of Overweight and Obesity? Retrieved from the U.S Department of Health and Human Services website; http://www.nhlbi.nih.gov/health/healtht-topics/topics/obe/risks.html

National Limb Loss Information Center. (2007). Limb loss in the United States. Amputee Coalition of America. Retrieved from website: http://www.amputee-coalition.org/fact_sheets/limbloss_us.pdf

NHS Choices. (2012). Amputation - How it is performed. Retrieved from website; http://www.nhs.uk/Conditions/Amputation/Pages/how-it-is-performed.aspx

Østlie, K., Skjeldal, H.O., Garfelt, B., & Magnus, P. (2011). Adult acquired major upper limb amputation in Norway: prevalence, demographic features and amputation specific features. A population-based survey. *Journal of Disability and Rehabilitation*. 33(17–18): 1636–1649

Pavlou S. Z. (July 15, 2008). Growing by the Waistline: BMI and Amputees. O&P Business News. Retrieved from the website; http://www.healio.com/orthotics-prosthetics

Pezzin, L. E., Dillingham, T. R, Mackenzie, E. J., Ephraim, P. & Rossbach, P. (May, 2004). Use and Satisfaction with Prosthetic Limb Devices and Related Services. *Archives of Physical Medicine and Rehabilitation*. 85(5):723-9.

Preedy, V. R. (2012). Handbook of Anthropometry: Physical Measures of Human Form in Health and Disease. DOI: 10.1007/978-1-4419-1788-1. Spinger Science + Business media LCC.

Public Health Agency of Canada. (2009). Tracking Heart Disease and Stroke in Canada, 2009. Retrieved from: http://www.phac-aspc.gc.ca/publicat/2009/cvd-avc/pdf/cvd-avs-2009-eng.pdf

Public Health Agency of Canada. (2011a). Diabetes in Canada: Facts and figures from a public health perspective. Retrieved from: http://www.phac-aspc.gc.ca/cd-mc/publications/diabetes-diabete/facts-figures-faits-chiffres-2011/pdf/facts-figures-faits-chiffres-eng.pdf

Public Health Agency of Canada. (2011b). Obesity in Canada - Health and Economic Implications. Retrieved from: http://www.phac-aspc.gc.ca/hp-ps/hl-mvs/oic-oac/econo-eng.php

Pylatiuk, C., Schulz, S., & DöDerlein L. (December 2007). Results of an Internet survey of myoelectric prosthetic hand users. *Prosthetics and Orthotics International*. *31*(4): 362 – 370

Racy, J. C. (2002). Psychological Adaptation to Amputation**.** In Bowker, H. K. & Michael J. W. (Eds.), Atlas of Limb Prosthetics: Surgical, Prosthetic, and Rehabilitation Principles. Rosemont, IL. *American Academy of Orthopedic Surgeons*, 2nd Edition.

Resnik, L., Meucci, R. M., Lieberman-Klinger, S., Fantini, C., Kelty, D. L., Disla, R., & Sasson, N. (2012). Advanced Upper Limb Prosthetic Devices: Implications for Upper Limb Prosthetic Rehabilitation. *Archives of Physical Medicine and Rehabilitation.* 93:710-7.

Rexrode, K. M., Carey V. J., Hennekens C. H., Walters, E. E., Colditz, G. A., Stampfer, M. J.,….& Manson, J. E. (1998). Abdominal obesity and coronary heart disease in women. *The Journal of the American Medical Association. Volume 280.* (21):1843-8.

Rich-Edwards, J. W., Manson. J. E., Hennekens, C. H. & Buring J. E. (1995). The primary prevention of coronary heart disease in women. *New England Journal of Medicine.* 332:1758.

Roberts, K. C., Shields, M., de Groh, M., Aziz, A., & Gilbert, J. (2012). Overweight and obesity in children and adolescents: Results from the 2009 to 2011 Canadian Health Measures Survey. *Health Reports 2012*. 23(3):3-7.

Ryan, T. (August/September 2012). Upper-limb amputees gain skills and independence from specialized rehabilitation. *Amp it Up Magazine Issue No. 03.*

Saradjian, A., Thompson, R. A & Datta, D. (2008). The experience of men using an upper limb prosthesis following amputation: Positive coping and minimizing feeling different. *Journal of Disability and Rehabilitation. 30*(11):871-883.

Shai, A. & Maibach, H. I. (2005). Wound Healing and Ulcers of the Skin: Diagnosis and Therapy – The Practical Approach. New York: Springer

Shaperman, J., Landsberger, S. E., & Setoguchi, Y. (2003). Early Upper Limb Prosthesis Fitting: When and What Do We Fit. *Journal of Prosthetics and Orthotics. 15*(1):11-17

Simko, M. & Cowell, C. (1995). Nutrition Assessment: A Comprehensive Guide for Planning Intervention. 2nd Edition. Jones and Bartlett.

Smith, D. G. (March/April 2006). Congenital Limb Deficiencies and Acquired Amputations in Childhood, Part 2 Emotional Response and Early Management. *inMotion Volume* 16, Issue 2.

Smith, D. G. (2006). Congenital Limb Deficiencies and Acquired Amputations in Childhood, Part 3. *InMotion*, *16*(3)1. Retrieved from website; http://www.amputee-coalition.org/inmotion/may_jun_06/congenital_part3.html

Smith, D. G. (2006). Congenital Limb Deficiencies and Acquired Amputations in Childhood. *InMotion*, *18*(1)1. Retrieved from website; http://www.amputeecoalition.org/inmotion/jan_feb_06/congenital_part1.html

Smurr, L.M., Gulick, K., Yancosek, K. & Ganz, O. (April-June, 2008). Managing the Upper Extremity Amputee: A Protocol for Success. *Journal of Hand Therapy*. *21*(2)160-75.

Soomro, N., Bibi, R., Ahmed, S. I., Kamran, B., Minhas, M. A., Siddiqui, K. Y. (2013). Epidemiology of amputation; low resource community: Sindh Province, Pakistan. *Professional Medical Journal*. 20(2): 261-265

Medicine. 332:1758.

Stamler, J., Vaccaso, O., Neaton, J. D. & Wentworth D. (1993). Diabetes, other risk factors, and 12-yr cardiovascular mortality for men – the Multiple Risk Factor Intervention Trial. Diabetes Care 16:434– 44.

Statistics Canada. (June, 2013). Self-reported adults BMI. Retrieved from the website; http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health82a-eng.htm

Statistics Canada. (October, 2011c). Mortality, summary list of causes 2008.

Stineman, M. G., Kwong, P.L., Kurichi, J. E., Prvu-Bettger, J. A., Vogel, W. B., Maislin, G.,….& Reker, D. M. (October, 2008). The effectiveness of inpatient rehabilitation in the acute postoperative phase of care after transtibial or transfemoral amputation: Study of an integrated health care delivery system. *Archives of Physical Medicine and Rehabilitation 89*(10):1863-1872.

Tank, P. W. (2009). Bones of the Upper Limb. Department of Neurobiology and Developmental Sciences, University of Arkansas for Medical Sciences. Retrieved from website; http://anatomy.uams.edu/anatomyhtml/bones_upperlimb.html

The Atlantic Clinic for Upper Limb Prosthetics. Retrieved from the website; http://limbclinic.com/about-us.php

Tzamaloukas, A. H., Patron, A., & Malhotra, D. (1994). Body mass index in amputees. *Journal of Parenteral and Enteral Nutrition*. *18*:355–8

Tzamaloukas, A. H. & Murata, G. H. (1996). Estimating urea volume in amputees on peritoneal dialysis by modified anthropometric formulas. *Advances in peritoneal dialysis. 12*:143-6.

Ulijaszek, S. J. (1994). Anthropology: The Individual and the Population. Cambridge University Press.

Veves, A., Giurini, J. M., & LoGerfo, W. F. (2006). The Diabetic Foot: Medical and Surgical Management. 3rd Edition. New Jersey, USA: Humana Press Inc. p523–42.

Watve, S., Dodd, G., MacDonald, R., & Stoppard, R. E. (2010). Upper limb prosthetic rehabilitation. *Orthopaedics and Trauma*. *25*(2) 135-142

Wilkins, K., Campbell, N. R. C., Joffres, M. R., McAlister, F. A., Nichol, M., Quach, S., Johansen H. L., & Tremblay M. S. (2010). Blood pressure in Canadian adults. *Health Reports* 2010. 20(1):1-10.

Willett, W. C, Manson J. E, Stampfer, M. J., Colditz, G. A., Rosner, B., Speizer, F. E., & Hennekens, C. H. (1995). Weight, weight change and coronary heart disease in women. *The Journal of the American Medical Association.* 273:461– 5.

Williams, M. R., Ehde, M. D., Smith, G. D., Czernieck, M. J., Hoffman., J. A. & Robinson, R. L. (2004). A two-year longitudinal study of social support following amputation. *Journal of disability and rehabilitation. 26* (14/15), 862-874

Wolfus, S. (October 14, 2012). Amputee Weight Loss: How to Calculate Amputee BMI. Retrieved from website; http://www.amputee-life.org/2012/10/14/amputee-weight-loss/

Woods, C. (July 30, 2011.) How to Adjust Calorie Needs for an Amputation. Retrieved from website; http://www.livestrong.com/article/505596-how-to-adjust-calorie-needs-for-an-amputation/

Woodward, M., Sussman, G., Rice, J., Ellis, T., & Fazio, V. (2009). Expert Guide for Healthcare Professionals: Nutrition and Wound Healing. Retrieved from website; http://www.awma.com.au/publications/2009_vic_expert_guide_nutrition_wound_healing.pdf

World Health Organization. (2004). The Rehabilitation of People with Amputations. Retrieved from the website; http://www.posna.org/news/amputations.pdf

World Health Organization. (May 2012). Obesity and overweight. Fact sheet N°311. Retrieved from the World Health Organization website; http://www.who.int/mediacentre/factsheets/fs311/en/index.html

Wright, T. W., Hagen, A. D., & Wood, M. B. (July 1995). Prosthetic usage in major upper extremity amputations. *Journal of Hand Surgery (American Volume).* 20(4):619-22.

Ziegler-Graham, K., MacKenzie, E.J., Ephraim, P.L., Travison, T.G., & Brookmeyer, R. (2008). Estimating the Prevalence of Limb Loss in the United States – 2005 to 2050. *Archives of Physical Medicine and Rehabilitation.89*:422-429.

Appendix A

The International Classification of Adult Weight According to BMI

Classification	BMI(kg/m^2)	
	Principal cut-off points	**Additional cut-off points**
Underweight	**<18.50**	**<18.50**
Severe thinness	<16.00	<16.00
Moderate thinness	16.00 - 16.99	16.00 - 16.99
Mild thinness	17.00 - 18.49	17.00 - 18.49
Normal range	**18.50 - 24.99**	**18.50 - 22.99**
		23.00 - 24.99
Overweight	**≥25.00**	**≥25.00**
Pre-obese	25.00 - 29.99	25.00 - 27.49
		27.50 - 29.99
Obese	**≥30.00**	**≥30.00**
Obese class I	30.00 - 34.99	30.00 - 32.49
		32.50 - 34.99
Obese class II	35.00 - 39.99	35.00 - 37.49
		37.50 - 39.99
Obese class III	≥40.00	≥40.00

Source: Adapted from WHO, 1995, WHO, 2000 and WHO 2004.

Appendix B

Acquired Clients within Working Age Subset

Age	Gender	Dominace Side	Level of Loss	Type of Loss	Timelapse (mth) B4 Prosfit	Distance From Fredericton	BMI	Total Visit Fitissue	Avelength of Days	Body Weight
30	0	0	5	1	15	346	26.92	5	2.2	3
36	0	1	6	1	18	290	31.49	0	0	4
25	1	0	3	1	4	216	19.82	3	1.3	2
37	1	0	3	1	5	1	26.15	1	2	3
62	0	1	3	1	4	70	27.74	0	0	3
52	0	0	5	1	6	331	30.62	1	1	4
66	0	1	3	1		185	29.11	0	0	3
70	0	1	5	1	8	10	40.39	1	2	4
57	0	1	3	1	2	53	29.38	2	2.5	3
59	1	0	5	1	13	138	25.42	1	1	3
75	0	0	5	1	10	115	22.77	0	0	2
66	0	0	3	1	18	160	29.71	3	1	3
47	0	0	3	1	5	1	40.35	7	1	4
69	0	0	1	1	33	119	33.46	1	1	4
47	1	0	3	1	5	180	22.71	2	1	2
27	0	1	3	1	7	121	20.8	1	1	2
48	0	1	5	1	12	30	26.92	2	1	3
38	1	0	5	1	13	554	45.54	1	1	4

Appendix C

Congenital Clients within Working Age Subset Population

Age	Gender	Dominace Side	Level of Loss	Type of Loss	Timelapse (mth) B4 Prosfit	Distance From Fredericton	BMI	Total Visit Fitissue	Avelength of Days	Body Weight
20	0	0	3	0	60	25	24.67	2	1	2
30	1	0	2	0	12	122	20.55	9	1	2
36	0	1	3	0	60	667	29.43	9	3.1	3
17	1	0	3	0	5	1699	21.49	4	4	2
24	0	1	3	0	6	423	19.68	3	3.3	2
22	1	1	3	0	7	286	30.18	0	0	4
23	1	0	3	0	6	111	23.35	18	1.3	2
23	1	1	3	0	5	984	20.29	6	4.8	2
22	1	1	3	0	5	824	25.5	6	1.6	3
22	1	0	3	0	5	389	23.46	10	2.2	2
32	0	0	3	0	9	131	20.8	19	1.2	2
32	1	0	3	0	28	816	35.67	11	1.1	4
21	0	1	2	0	36	1721	20.34	2	3	2
46	0	1	3	0		4775	26.45	2	1	3
30	0	0	3	0	9	388	31.79	3	2	4
54	0	1	3	0		452	37.54	0	0	4

Appendix D

Brochure on Upper Limb Amputation and Nutrition

UPPER LIMB AMPUTEE

TAKING CONTROL OF YOUR WEIGHT

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UPPER LIMB AMPUTEE

TAKING CONTROL OF YOUR WEIGHT

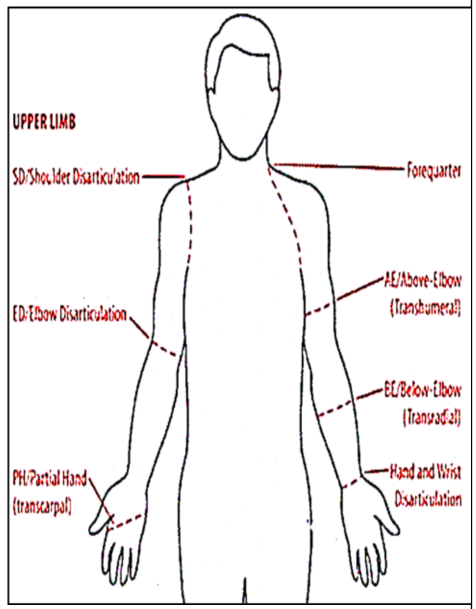
Did you know that;

- Individuals experiencing amputation of a limb or limbs may have more difficulty with weight control.
- Amputation results in reduced body mass meaning that your basic nutritional needs are now lower, so eating at previous levels could cause weight gain.
- Adjusted body weight is more reliable than observed weight in individuals with limb amputation.

OVERWEIGHT IMPLICATIONS

- You are more likely to suffer from obesity related diseases (heart disease, diabetes, high blood pressure and cholesterol by failing to accurately identify your overweight status.
- You may have fit issues; your prosthetists may be challenged with finding myoelectric sites, determining the best socket design and resolving harnessing issues.

Upper limp amputation categories



(Source: Atlantic Canada Upper Limb Prosthetic Clinic)

To calculate your BMI as an acquired amputee, your true body weight (TBW) that is your body weight before amputation is needed. In order to do this, the corresponding average % total weight of the amputated limb is used.

The equation for true body weight is given as:

$$\frac{\text{Present body weight}}{100 - (\text{weight \% of the amputated limb})} \times 100$$

Point to note

- Although BMI is useful for creating guidelines in healthy adults (ages 18 to 65), it does not apply to infants, children, adolescent, pregnant or breastfeeding women, older adults (over 65years) and muscular individuals.

- Overweight issues affect lower limb amputees more than upper limb amputees because of weight bearing issues when fitting prostheses.

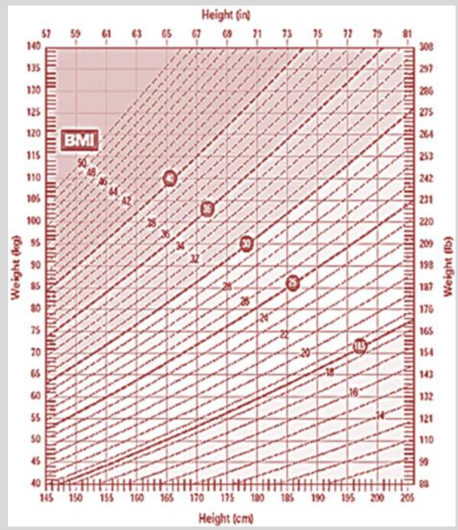
Adjustment of Body weight for Amputees

Body Segment	Average % of Total Weight Amputated
Lower arm and hand	2.3
Trunk without extremities	50.0
Entire arm	5.0
Hand	0.7
Entire lower leg	16.0
Below knee including foot	5.9
Foot	1.5

Source; Mahan et al., 2012

Example: For a transradial amputee your corresponding average % total weight of the amputated limb is 2.3. With present weight of 63.5kg and height of 169cm your true body weight

$$= \frac{63.5}{100-2.3} \text{ x } 100 = 64.99 \approx 65\text{kg}$$



To estimate BMI, locate the point on the chart where your true body weight and height intersect. Read the corresponding number on the dashed line closest to the point. For example, with true body weight of 65kg and height of 169cm, you have a BMI of approximately 23 which is normal.

You can also calculate your BMI using this formula:

$$\text{BMI} = \frac{\text{True body weight (kg)}}{\text{Height}(\text{m}^2)}$$

Health Risk Classification According to Body Mass Index (BMI)

Classification	**BMI Category (kg/m^2)**	**Risk of developing health problems**
Underweight	< 18.5	Increased
Normal Weight	18.5 - 24.9	Least
Overweight	25.0 - 29.9	Increased
Obese class I	30.0 - 34.9	High
Obese class II	35.0 - 39.9	Very high
Obese class III	>= 40.0	Extremely high

Source: Health Canada. Canadian Guidelines for Body Weight Classification in Adults. Ottawa: Minister of Public Works and Government Services Canada; 2003.

- Body mass index (BMI) is the most well-known indicator of body fatness.

- BMI values are age independent and the same for both sexes (adults).

- Using actual post-amputation weight significantly underestimates BMI.

How to reduce your risk

- Drink lots of water.
- Avoid fad diets.
- Lower intake of trans and saturated fat foods.
- Engage in physical activity that will not put strain on your good arm.
- If required, seek education and nutrition counselling.

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Vita

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Factors that influence the post-harvest quality changes in Oranges (*Citrus sinensis*) under different storage conditions and time (2003).