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Rehabilitation Process of Lower Extremity Amputees

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Appendix D - UNIVERSITY HONORS PROGRAM
SENIOR PROJECT - APPROVAL

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PROJECT TITLE: Rehabilitation Process of Lower Extremity Amputees

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

Signed: Jack Wasserman, Faculty Mentor

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Comments (Optional):
Rehabilitation Process of Lower Extremity Amputees

Presented by: Kenyail C. Norris

Presented to: Dr. Broadhead

Senior Honors Seminar

May 1, 2000
DEDICATION

I would first like to dedicate this report to my Lord and Savior Jesus Christ for giving me this opportunity to interact with individuals that see the true meaning of life through their trials and tribulations. I am now reminded of how blessed I am to have a fully functioning body that I often take for granted. Sometimes we miss the “little things” in life.

I would like to dedicate this paper to all of the therapists, prosthetists, and physicians who spend their days committed to improving the everyday life of these patients. Through my observations, I witnessed a lot of heartache and frustration that these individuals sustained for the sake of their patients.

Lastly, I would like to thank all of the patients in the Patricia Neal Rehabilitation Center for being so willing to share their stories and experiences with a complete stranger. Through your trials and tribulations, failures and accomplishments, I not only realized what true motivation was, but I was able to witness the true beauty of God’s creations through His power of healing.

Memory verse: “I can do all things through Christ who strengthens me.”

Philippians 4:13
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I would first like to thank Dr. Jack Wasserman, my faculty advisor, for contributing his knowledge in the classroom and outside expertise throughout my biomedical engineering undergraduate career.

Next, I would like to thank Paula Minhinnet, Volunteer Coordinator for the Fort Sanders Regional Medical Center, for working so diligently in getting me positioned exactly where I asked. She provided a very unique opportunity for me and for that, I thank her.

My gratitude goes to Camelia Williams, Manager of Rehabilitation Therapies, for allowing me to “disrupt the flow” for a little while.

Lastly, I would like to thank Dr. James Fox for allowing me to sit in on his Amputee Clinics and experience, first hand, exactly how demanding the amputee field can be.
ABSTRACT

This study explores the ever-growing population of lower extremity amputees and examines the physical and mental aspects of rehabilitation for lower extremity amputees.

Every year, the population of lower extremity amputees increases drastically. Lower extremity amputation is often the result of diabetes, malignant tumors, or car accidents. In these cases, the surgeon is often unable to save the individual's limb or the patient has a choice between life and death. A modern view on lower extremity amputation, suggested by Weiss, calls for the formation of a novel organ (a stump equipped with appropriate morphologic and functional features). The proper healing condition of the stump, relating directly to the skin flap incision created during surgery, is an important topic as well. Following proper healing, the patient must achieve the proper level of rehabilitation, or health, and be evaluated for his or her prosthesis. Adequate candidates must have good cardiac stability in order to endure the stresses applied on the body with the use of the prostheses.

By observing at Ft. Sanders Regional Medical Center, I obtained priceless "first-hand" knowledge on not only the pain, but also the joy experienced by the amputee during rehabilitation. This research seeks to realistically characterize the entire spectrum of both tribulation and celebration in the lower extremity rehabilitation process and develop a means of evaluation of the level of success achieved thereafter.
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INTRODUCTION

The number of amputees is growing more and more rapidly every day. Amputations are a result of various occurrences such as war wounds, automobile crashes, work-related accidents and a need for disease control in the body to preserve life. Along with these amputations, the removal of any portion of an arm or leg, mankind developed artificial replacements, or prostheses. “Prostheses were developed for function, cosmetic appearance, and a psycho-spiritual sense of wholeness but not necessarily in that order” (10). This report will explore, in detail, the rehabilitative process of lower extremity amputees, from the point of amputation, through the lapse time of healing and physical therapy, to the fitting of the artificial limb and learning how to use it efficiently. Furthermore, the paper will focus on the everyday rehabilitative measures taken by both the physical and occupational therapists and the patient. Physical, emotional, and mental problems will be addressed as well as possible solutions. We would like to believe that this phenomenon of amputation is distant and only affects few. But the truth is, we often choose to ignore the pains of such a “social tragedy”, feeling as though we would no longer be accepted by even our loved ones and friends. For any individual involved in everyday traveling and living, the information presented could someday become of great importance in the restoration of normal living for you, or even a loved one.
The majority of the information gathered for this report emerged from observations at the Ft. Sanders Regional Medical Center in Knoxville, Tennessee. The focus reflects three distinct departments of the Ft. Sanders Regional Medical Center: the Occupational Therapy division, the Physical Therapy and Outpatient Center, and the Rehabilitation Physicians Office—all under the esteemed Patricia Neal Rehabilitation Center.

"The Patricia Neal Rehabilitation Center (PNRC) Orthopedic Program is designed to increase the functional independence and safety of the post surgical hip and knee patient, as well as other complex orthopedic dysfunctions" (6).

Patricia Neal Rehabilitation Center (1997)

Occupational Therapy

The Occupational Therapy division of the Patricia Neal Rehabilitation Center is the initial focus. According to OT Clayton Karr (3), the primary purpose of the Occupation Therapy division is to provide a sufficient amount of independence for the patients in their daily living activities such as homemaking skills and lower body hygiene and dressing. Transfer skills, like in and out of the bathtub, are emphasized throughout this department. A patient must prove that he or she is capable of doing these activities before the therapist will release the patient. In addition, if the patient needs any adaptive equipment at home, the occupational therapist (OT) will instruct the
patient on the usage of that equipment to avoid any type of unnecessary injury. Oftentimes, the OT takes a home assessment, and if needed, modifications can be made for the patient's special needs.

**Physical Therapy and Outpatient Center**

The Patricia Neal Outpatient Center also plays an enormous part in the independence of the patients. This division acts as the "periodical rehabilitation home" for patients that have been discharged from the hospital. By this point, several weeks have passed between the time of discharge, acquiring a fitting for the prosthesis. With respect to lower extremity amputees, the Outpatient Center is the place where the patients learn how to walk with their new prostheses. Physical therapists also inform and train patients in post-surgical precautions. According to PT Susan Murphy (4), the patients are instructed on how to use their assistive aids such as canes, crutches, or walkers. Exercises become a little more involved because they begin to focus on the strengthening of joints and muscles.

**Rehabilitation Physicians Office**

The final division of the Patricia Neal Rehabilitation Center is the Rehabilitation Physicians Office. This department houses Amputee Clinics that serve as "gathering places" for the physician, the prosthetist or othotist, the physical therapist, and the patient. According to Dr. James Fox (2), he and other individuals come together to evaluate a variety of cases and make
recommendations to outside parties such as the primary prosthetist or insurance companies to obtain special equipment for the patient. The evaluation begins with questions by all participants to gain a better understanding of past history and possible trends for future occurrences. Both past and current health conditions are especially important in the consideration for the first, or temporary, prosthesis. Balance and upper body strength are briefly evaluated to see if additional in-patient therapy is needed. If the patient already has a prosthesis, he or she is able to explain any discomfort or "out-of-the-ordinary" things that may have taken place since the last doctor's visit. This collaborative effort allows phenomenal expertise to be encompassed in one room, at one time, to maximize the level of problem solving for the patient.
INDIVIDUAL CASES

Amputation for individuals occurs for several different reasons, such as those previously mentioned. However, the next sections cover specific cases studied at the Ft. Sanders Regional Medical Center in Knoxville, Tennessee.

Patient #1

The first patient observed, “Patient #1” (all specific information disclosed), was a unilateral (single-sided), transfemoral (above the knee) amputee (example seen in Figure 1). Now approximately in his mid-fifties, he recently lost his leg as a result of diabetes. Originally, the surgery was only supposed to consist of the amputation of his toes and half of his foot. However, after the surgery this patient’s foot turned black from poor circulation possibly caused by the staples inserted during surgery. As a result, a second surgery was performed, and his leg is now amputated above the knee and healing perfectly. Even when the patient used peroxide to clean the incision, no foaming occurred. He now resides in a wheelchair to which a wooden plank is inserted into the corresponding side, so his stump can rest comfortably. The use of the wooden plank is a common apparatus used for lower extremity amputees. Due to severe atrophy (weakening and shrinkage) of the heart muscle, a wheelchair will more than likely be Patient #1’s primary mode of mobility. The cardiac instability or weakened heart condition also prohibits Patient #1 from being a good candidate for a
prosthesis. Upper body strength, which will be covered under rehabilitation, is a necessity for both a prosthesis and everyday activities. Patient #1 also mentioned a phenomenon called phantom pains, which will be discussed in a later section.

![Figure 1: Above the knee amputee.](image)

**Patient #2**

The second patient observed, “Patient #2” (all specific information disclosed), was a bilateral (both sides), transtibial (below the knee) amputee (example seen in Figure 2). Patient #2 is also approximately in his mid-fifties. This individual lost his first leg (right) due to a malign tumor. Two days after his first amputation, the physician noticed yet another tumor in the opposite (left) leg. As a result, the amputation of this patient’s legs occurred almost simultaneously. Because of the bilateral amputation, Patient #2 has more difficulty with things such as rolling over and must depend even more on upper body strength.
Patient #3

"Patient #3" was a unilateral, upper transfemoral (total hip prosthesis) amputee (example in Figure 3). She lost her entire leg due to a blood clot. Patient #3 is approximately in her mid-sixties to seventy years of age. As a result of the blood clot, she had to have a bypass placed in her upper thigh along with her amputation. This patient's biggest irritation was that her prosthesis rubbed the upper, inside portion of her leg raw. In conclusion, any ambulatory activity caused irritation and extreme discomfort from a pinching mechanism. The unique thing about this patient is that originally her physician did not evaluate her as being a good candidate for a prosthesis. However, because she persisted on having such an aid, the physician eventually approved the patient's request. Patient #3 has successfully gone
through rehabilitation with the total hip prosthesis for approximately three months.

Patient #4

The experience of the next patient mentioned is a rare and special case. It involves a woman in her mid fifties to sixties and an accident at a skating (roller) rink. As she was skating with two smaller children, a passing skater knocked her off balance resulting in a fall that fractured her ankle. A fractured ankle.....a pretty common injury. Millions, if not billions, of ankle fractures occur a year, but how many of them result in an amputation and prosthesis for life? For this individual, routine surgery and the addition of pins was the next step. After the implementation of pins during surgery, Patient #4 went home in a cast and was non-weight bearing for six months until she returned to the doctor. Upon examination, the doctor realized that her ankle had
collapsed in the cast. The suggestion at this point was fusion of the bones in her ankle. But as patients often do, she did not feel comfortable and wanted to give this more consideration. Meanwhile, the intensity of the pain in her ankle increased by the hour. The pain became so severe that after a period of time, the patient became depressed and had to be hospitalized. At the hospital, the doctor informed her that the fusion of her ankle was now urgent. After further assessment, the doctor determined that for an unknown reason, the patient’s anklebones had deteriorated from the previous surgery procedures. As a result, the surgeon had to shorten the patient’s leg one and a half inches. Between the course of this first attempt at fusion and the actual amputation of the leg, approximately 30 surgical procedures took place for this one individual. There was very little lapse time between surgeries, and by the end, the patient’s leg was a total of three and a half inches shorter. During the course of the surgeries, other problems arose. Poor blood flow produced the need for both pelvic and arteriole grafts from the contralateral leg. Even though the contralateral leg was healthy at this point in time, it gradually became weaker. No more could be done in this unexplainable event. Patient #4 lost her leg and became a transtibial (below the knee) amputee in July of last year.

As seen, each case is unique. However, the surgical and rehabilitation processes for amputees are, in general, consistent throughout the world.
LEVELS OF AMPUTATION

The determination of the amputation level prior to actual surgery is one of the most essential factors. It requires taking into account many elements—such as the patient’s age, sex, general condition, extensiveness of and degree to which the tissues suffered damage in trauma, and the vascular supply in the limb. However, it must be understood that it is not always possible to determine all of these factors prior to surgery. Take for instance, a patient with a tumor or diabetes. The actual area infected may spread between the time of the most recent pre-surgical test and the time the patient enters the operating room. As a result, the surgeon may now have to amputate a greater portion of the leg than was expected before the surgical procedure began.

Modern views on lower extremity amputation call for the formation of a novel organ, a stump equipped with appropriate morphologic and functional features that are shown on the next page in Figure 4 (9).

There are approximately eleven different sites for possible amputation. Amputation at levels one or two saves all portions of the leg above the toes, which is beneficial if the toes are painful, stiff, or with sensory disorders. Amputation level three results in an excellent weight-bearing stump, but because of cosmetic reasons, it is not recommended for women. The zone between levels three and four is prohibited. Levels six and seven are functionally useless and therefore amputation should be performed at a
higher level. Amputation at level seven produces a good weight-bearing stump, but is a non-cosmetic fitting region. As a result, it is recommended for older persons and children. In addition, level eight is also an excellent weight-bearing stump for patients of all varieties. Examining level nine, this region is a selective level for myoplastic amputations and modern fitting. For the region surrounding levels ten and eleven, attempts should be made to save the femur and trochanteric block in hip joint disarticulation.

As seen, much of the future success for the amputee could greatly depend on the procedures from the very beginning of surgery. Not only is the region of amputation important, but also the covering of that region with the skin.
Figure 4: Selective Levels of Lower Extremity Amputation According to J. Krol, Crirurgia Narzadow. (Weiss)
SKIN FLAPS

The patient initially has swelling, soreness, and irritation of the stump, or amputated limb, for several days if not weeks after surgery. To aid in the decrease of these inevitable, post surgical events, the method or technique for the skin flap can be extremely important. The development of these techniques is still evolving, so surgeons seem to choose the technique with which they are most comfortable. One particular method of a skin incision technique in amputation, according to Kocher, can be seen below in Figure 5 (9).

Figure 5: Development of Skin Incision Technique in Amputation, According to Kocher. (Redrawn from W. Marquardt Gliedermassenamputationen und Gliederersatz, 1950). (Weiss)
As seen, surgeons first used skin-only, circular incisions. Later, techniques added an oblong incision at the lateral face of the extremity. This soon became known as a rocket incision. After further development, surgeons added a second oblong incision on the contralateral face. With a two-sided, oblong incision, this method became the predecessor for the lobal or flap incision. In general, many accepted the fact that a doctor by the name of Lowdham introduced this phenomenon. It was only later that such a quantum leap occurred as Neudorfer and Ravaton added on to the flap incision technique by changing from skin-only to both skin and muscles. This technique proved important because it provided “a stump covered with skin of high value” (9).

According to Weiss (et al), a high valued stump consists of several criteria. First, the skin should be smooth and unwrinkled. There should only be moderate subcutaneous fatty tissue (underneath the skin). Next, the scar should not affix to the end or base of the stump. Lastly, the scar should be positioned in a way that, with the use of prostheses, it would not be subjected to pressure. Although these specifications are indeed important, the patient can and does begin rehabilitation before they transpire.
HEALING

The healing process depends heavily on the patient, and slightly depends upon the actual place of amputation. Proper physical healing includes little to no inflammation of the stump, callused skin, and no tenderness. Psychological adaptation, including personal negativism, causes the patients recovery to be prolonged. It is often seen that patients with positive attitudes and a great desire to improve their well being recover a lot faster than those who tend to carry a bad attitude with them throughout therapy. Below is a list of typical situations that have been observed among amputees according to Weiss (9).

- General lack of training due to a long stay in a recumbent (lying down) position.
- Unsatisfactory psychological adaptation, and even personal negativism resulting for the long process of immobilization and no hope of unaided walking.
- Contractures (a permanent shortening producing deformity) of the stump.
- Poor condition of the stump-covering skin.
- Poor shape of the stump, resulting mainly in lack of biomechanical stabilization caused by the muscles clasping the bone stump only loosely.
- Pains upon palpation (to examine by touch).
- Pains upon stressing the stump (i.e. with a prosthesis).
- Phantom pains, requiring in a majority of cases application of local physiotherapy and frequent administration of anesthetics.
One condition mentioned above is very important and takes place in every amputee. Phantom pain is a serious matter because the patient must be able to distinguish between this pain and actual pain due to physiological problems. The body, at first, is not able to distinguish that a portion of the body is no longer present. Therefore, certain messages like itching or pain are still delivered to that specific part of the body. But how does a person scratch something that is no longer there? Many patients commented that it's best just to focus on something else until the feeling goes away. However, phantom pains are permanent. They never fully diminish; instead, they decrease in number over time.

As seen, the procedures and techniques used are very important in several different aspects of the patient’s recovery. Several of these points are addressed in more detail throughout the text.
Depending on each individual patient, both physical and physiological rehabilitation begins approximately only a few days after surgery. After a proper evaluation of the patient occurs, lower extremity patients normally start with exercises to build the upper body or extremities. On average, patients have a variety of six different rehabilitation sessions a day.

**Upper Extremity Rehabilitation**

According to Bob Babson (1), a rehabilitation tech, strengthening the upper body is extremely important when pertaining to lower extremity amputees. After amputation, a patient must depend on his or her upper body strength to do most, if not every activity each and everyday. Amputees use crutches, walkers, and/or wheelchairs for several months, all of which require a considerable amount of upper body strength.

Patients begin with resistance training and upper extremity classes. Resistance training involves equipment such as the hand bike (see Figure 4) or apparatus for wheel chair push downs. Upper extremity classes become a fun and integral part of rehabilitation for the patients. It breaks the possible monotony of normal activities and involves several interesting conversations to preoccupy the mind. One of the favorites is called "Money Tree". In this exercise, the patients pretend that there is a huge tree with ten, twenty, or even one hundred-dollar bills attached. In order for the patients to obtain the
money, they must sit at the edge of their wheelchairs, sit up tall, and reach (one arm at a time) stretching as far up as possible. Additional exercises such as elbow extensions and seated rows can be viewed in Appendix B.

![Hand Bicycle for Resistive Training](image)

Figure 6: Hand Bicycle for Resistive Training (Patricia Neal Occupational Therapy, 2000).

**Occupational Rehabilitation**

Other crucial skills are attained in occupational rehabilitation where the patient gains the ability to function efficiently in daily activities such as going to the rest room, taking a shower, and clothing oneself. As seen in Figure 5, the bathroom facility is set up similar to that which the patient will be returning. In the top picture, a patient uses a shower bench to increase the easiness of taking a shower on his or her own. According to Bubba Sawicki (8), the patient is able to roll the wheelchair fairly close to the edge of the bathtub. The extended side of the bench allows the patient to slide on and off
the wheelchair and into the shower with increased ease. The patient can then become self-reliant and feel comfortable about performing daily activities alone.

During occupational therapy, patients also learn proper hygiene for their stump (see Appendix C). They are told to wash the stump with soap and lukewarm water. The amputee must be sure to rinse off all soap residues because it may cause irritation to the skin. The patient must also be cautious not to saturate the skin with water to avoid softening of the skin and possible swelling. The patient then needs to gently dry the skin of the stump. Apart from the actual cleaning of the stump, the patient massages his or her stump to increase tolerance to pressure and to help decrease the sensitivity of the stump. Along with “do’s” there are always “don’ts”. The patient should not apply creams or moisturizers to the stump, nor should he or she shave the stump. Irritation is a serious matter because it can lead to infection, which could result in additional amputation.
Figure 7: Occupational Therapy Bathroom Facility- (1) Shower Chair with Extended Sides (top) and (2) Toilet Aid for Wheelchair Patients (bottom).
Lower Extremity Rehabilitation

Along with the previously mentioned activities, amputees also increase lower body strength in both the normal leg and the stump. Various positions and exercises are noted in Appendix D for both below the knee and above the knee amputees. Positioning exercises are important because lower extremity amputees need to obtain full extension of their amputated leg. The leg naturally wants to flex, known as contracture. However, for future use of a prosthesis, contracture makes the fitting almost impossible in both function and comfort. In addition to contracture, the muscles of the amputated leg(s) experience atrophy or shrinkage. The goal of the therapist and patient is to reduce as much muscle atrophy as possible, especially if the patient is a future candidate for a prosthesis.

As one can see, the patient has very little time to regain not only physical strength but also confidence in his or her ability to function without depending on someone else. Dependency and availability of help at home dictate the patient’s path after the seven to ten days of rehabilitation and discharge. Discharged individuals either travel from their homes to the hospital for rehabilitation throughout the week, or receive home health care. If the patient has someone (such as a spouse or child) waiting at home, his or her skills may not have to be as good as someone who will be going home to an empty house. Many patients also lack transportation and therefore have home health care where a therapist comes to the place of residency and assists the patient in various exercises. These patients are attended to at
home instead of returning to the hospital's outpatient center. The completion of time spent in the Occupational Therapy department led to the follow-up department of the Patricia Neal Outpatient Center.
PATRICIA NEAL OUTPATIENT CENTER (PNOC)

The Patricia Neal Outpatient Center houses lower extremity amputees that have a prosthesis, or two, in the case of bilateral amputees. For a variety of reasons, not all patients make it to this level. Each patient must be evaluated upon discharge, and there it is decided whether or not the patient is a good candidate for a prosthesis. If the patient has atrophy, or shrinkage of the heart, he or she may not be able to withstand the stress posed on the heart by the prosthesis. Normally persons that have any kind of past or present chronic heart condition are persuaded against obtaining an artificial limb.

However, for those who do make the cut and obtain their prosthesis, a new world of challenges lies ahead. The physical therapist now has the responsibility of teaching the individual how to use his or her new leg in the correct way and with the most efficiency. The physical therapist first evaluates the patient's general strength and abilities. According to these observations, the therapist is able to set up a program that is unique to that patient. Both short and long term goals are set, along with general concerns that may need to be addressed at a later time.

Range of Motion (ROM)

By this time it is necessary for the stump of the patient to be shaped, which is obtained by the stump "shrinker", or cloth covering that is worn daily after discharge from occupational therapy. Range of motion is very important in
ambulatory activity, or walking with the prosthesis. As previously mentioned, without full extension of the stump, the fitting of the prosthesis becomes anatomically incorrect, and as a result, is dysfunctional and extremely uncomfortable.

**Strength and Balance**

Strength and balance are the first steps in learning the proper use of the prosthesis and other equipment aids. Patients begin with simple balancing by using assistive devices such as walkers or a piece of furniture (if at home). The therapist also requires the patients to learn lateral (side to side) and anterior-posterior (front to back) weight shifting. It is also beneficial for the patient to swing the prosthesis forward and behind for swing-phase control. Along with stationary exercises, the patient uses exercise equipment such as the NuStep machine. The NuStep machine allows the patient to move in almost a skiing motion but in a sitting position (see Figure 6). With these exercises, the patient begins on the floor but soon moves to small steps to increase skill. The exercises mentioned not only aid in balance, but they also strengthen the opposite and amputated leg. On average, it takes several weeks for the patient to gain sufficient balance and become comfortable enough to begin ambulatory exercises.
Ambulation

The physical therapist initially introduces the patient to the parallel bars seen in the figure below. The patient is able to hold on to the bars bilaterally (both sides) and support himself with each step. At the same time, the physical therapist assists the patient by holding onto a safety belt and guiding the patient through each exercise. The parallel bars provide maximum support, so if the patient cannot walk using this apparatus, he will not be able to walk out of the bars. Eventually, the lower extremity amputee becomes confident enough to learn how to use a walker, and eventually crutches, to assist him or her in the everyday activity of walking.
Success In Walking

In order for the patient to master the art of walking again, there are four basic exercises involved: balance control, knee control, adequate weight shift over the prosthesis, and forward progression (7). Over the years, therapists concluded that the more of the leg the person has, the easier. This means that a below the knee amputee has an easier time mastering the exercises mentioned above than an above the knee or total femoral amputee.

Even after these criteria are met, the patient still faces problem such as an inefficient gait. By this it is meant that the patient may have a slight hitch, or pause in stride because of discomfort.
CONCLUSION

Several important conclusions manifested through the observations at the Ft. Sanders Regional Medical Center. Proper healing of the stump skin covering did prove to be important, especially with patients who used a prosthesis. The amount of soreness dictated exactly how long each individual could tolerate the pain or discomfort of the prosthesis. This may not seem to be a problem at first, but pain should not be the limiting factor. If a patient is able to tolerate the stress placed on the heart, then he or she should (in reality) be able to wear the prosthesis as long as desired. If this were the case, the patient could become more independent both physically and mentally. Therefore, it is suggested that further development be made in the actual method of skin incision to increase the effectiveness of the prosthesis. It may be possible to make a double layer of skin instead of a single layer. The harvesting of muscle from the amputated portion to add on to the remaining muscle may also be a possibility.

Another issue addressed concerns the criteria for a patient to be able to withstand the stresses produced by a prosthesis. Patient #3 acquired a prosthesis even after the physician recommended otherwise. This leads to the belief that the physician may want to consider another set of standards or guidelines in assessing each patient for the use of a prosthesis. There is a biomechanical phenomena called Wolff's law that states (in bone in particular) that the strength of certain components of the body responds directly to the amount of stress placed on that component. In other words, why not slowly
increase the use of a prosthesis for the patient to allow the body to increase in strength while adjusting to the stresses produced by the prosthesis. The initial and periodical evaluations would have to determine the rate at which the patient would be allowed to proceed.

For those patients that had the opportunity to obtain a prosthesis, the success rate seemed to be well above 80%. The patients observed were happy to have the opportunity to be able to walk again, disregarding the fact that the use of the prosthesis was not an all day event. However, in the eyes of the patient, minimal walking was better than no walking at all.
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Appendix A
Contains Information on the History of Prostheses
Humans developed a need for prostheses back as far back as the eighteenth century. It is interesting to see how such a need arose and how much development has occurred thus far. Even though advances are apparent, it would appear that a majority actually occurred after the first fourth of the twentieth century until the present day.

The reasons for amputation in ancient times varied. Padula and Friedman report that it was common in Arabic countries where first cousins were encouraged to marry, congenital deformities have always been present. Whether in battle or taken prisoner by the enemy, war was often the cause of traumatic amputation. In the ancient Moche culture of Peru, amputation was also used as a judicial punishment. The punishment for theft was amputation of the hand, while a foot was removed for laziness and both arms for rebellion. Many ancient cultures had knowledge of amputating as a result of diseases such as tuberculosis, leprosy, and gangrene and advised amputation above the diseased area for healing (10).

True rehabilitation aids were first recognized in the great western civilizations of Egypt, Greece, and Rome. Several ancient civilizations had no written records, and the history of rehabilitation and prosthetic science was recorded orally in poems, sagas, and songs. In order for scientists to understand the renaissance of prosthetics, they rely on anthropology to interpret artwork, remains, and myths. An ancient sacred poem of India, the Rig-Veda, is said to be the first written record of prostheses. It recounts the tale of Queen Vishpla, a warrior who lost her leg in battle and was fitted with
an iron prosthesis and returned to battle (10). Actual prostheses for both hiding deformity and for battle were produced during the Dark Ages. Some of these prostheses made by armor makers for use in battle were somewhat advanced, but were usually heavy, cumbersome, and functioned only in battle. Legs were set to ride in stirrups and arms were set to hold shields at all times, but not for everyday functions such as walking. The knight usually wore peg legs or hand hooks for daily function.

The development of prostheses, from the 1600s through the 1800s was merely refinements of earlier armor type devices. In 1969, a Dutch Surgeon by the name of Pieter Andriannszoon Verduyn introduced the first non-locking, below knee prosthesis. It closely resembles today's joint and corset prosthesis. Like the joint and corset, it was made of external hinges and a leather cuff that bore weight. The leg cuff socket was lined with leather and had a copper shell and a wooden foot.

In 1800, James Potts of London designed a prosthesis that consisted of a steel knee joint, a wooden shank and socket, and an articulated foot that was controlled by catgut tendons from the knee to the ankle. After Marquis of Anglesey of Ireland lost his leg in the Battle of Waterloo, it became known as the Anglesey Leg. Knee flexion caused dorsiflexion of the foot, and knee extension caused plantar flexion of the foot.

In 1839, a gentleman by the name of William Selpho brought the Anglesey Leg to the U.S. In 1846 a patient of Selpho, Dr. Benjamin F. Palmer, obtained a patent for his leg that improved on the Selpho leg by
adding an anterior spring, smooth appearance, and concealed tendons. It was honored in 1851 at the London World's Fair: “It imparted a life-like elasticity and firmness to the step” (10).

In 1858 Dr. Douglas Bly of Rochester, New York invented the first curved knee joint that allowed for inversion and eversion through the use of an articulated ankle: a polished ivory ball in a socket of vulcanized rubber. Following the American Civil War, the industrial revolution brought about prosthetic advancement fueled by money available to amputees. Government support began to play a major role, and still does to this day, with the commitment to supply prostheses to veterans. Later, in 1912, an English aviator, Marcel Desoutter, made the first aluminum prosthesis after he lost his leg in an airplane accident. The Hanger Company advanced this invention.

In 1918, Dr. Martin described a prosthesis that emphasized the anatomy and physiology of the leg by reproducing the natural static and aesthetic appearance of the lower limb. It was made from measurements and a modified cast of sound and residual limb.

The Veterans Administration, HEW (Department of Health, Education, and Welfare), and the Armed Services sponsored the Artificial Limb Program by instituting a number of research laboratories such as the University of California at Los Angeles Laboratory for Upper Limb Study. Materials improved, as did socket designs such as the P.T.B. and the quadrilateral. Northrup Aviation introduced the use of thermosetting (becoming permanently
hard and unmoldable once subjected to heat) resins to form custom fit socket and structural components. As a result, the SACH foot that allowed for total contact along with clear check sockets.

1956 and 1959, respectively, the development of both the SACH foot (University of California) and the PTB prosthesis (University of California at Berkeley took place. Soon after, in 1971, the endoskeletal elements (internal bony structure) existed with a soft outside cover. From 1974 to 1976 the ROL, STAR, and Hosmer rotational units emerged, and in 1980 the SAFE foot (one of the first “energy storing feet”) surfaced to the industry (10).

Many corporations today, such as Hanger and NovaCare, are developing systems that surpass even the 1980 SAFE foot. Amputees can purchase prostheses for several different occasions such as running or skiing. Numerous amounts of money are being used for research to develop systems that actually return energy back to the user. This allows the apparatus to feel and perform more like the actual human body. In order to get this absorption and reaction, different materials such as titanium are being viewed along with a system of springs. Skiing systems have also been designed to allow amputees to get involved in more recreational activities. The question for the future, however, is exactly how will these “help aids” be handled when it comes to competitions. Should those with “help aids” be allowed to compete against those who simply perform from natural anatomy and capabilities?

As seen, the renaissance of prostheses has traveled throughout the world and continues to emerge today. How many years will it take the human
race to develop systems to take the place of any functional organ or body part? The possibilities are endless as long as the sky is the limit.
Appendix B
Contains Upper Extremity Exercises
1. Adduction, Overhead /w Elastic - 3 sets of 10 reps
Stand, or sit with your back supported. Raise both arms overhead as shown, holding on to the elastic. Pull the arms apart and downwards, stretching the elastic. Keep your arms out to the sides, not forward. Hold 0 seconds. Relax, and repeat 10 times. Sets: 3

2. Chest Pull with Band - 3 sets of 10 reps
Sit or stand with feet shoulder width apart. Loop band around each palm. Place arms in front of body with elbows slightly bent. Pull band outward and across chest, hold, and return to starting position. Do 10 repetitions, 3 times per day.

3. Flexion, Elastic Resistance - 3 sets of 10 reps
Stand on one end of the elastic. Hold the other end in your hand, thumb up. Pull forward, keeping your elbow straight. Hold for 0 seconds. Slowly return to the starting position. Repeat 10 times. Sets: 3

4. Seated Row with Band - 3 sets of 10 reps
Assume longsitting position with back straight. With band looped under both feet, hold each end of the band with elbows straight. Keep arms close to the sides of the body and pull arms/elbows back. Hold and lower slowly. Return to starting position. Do 10 repetitions, 3 times per day.

Please check when you have completed your exercises:

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5. Shoulder Abduction with Band - 3 sets of 10 reps
Sit or stand on firm surface with band held at hip or waist height. Point thumb toward ceiling. With elbow straight, raise involved hand up and away from side of body, hold, and return to starting position. Do 10 repetitions, 3 times per day.

6. ER, Bilateral, Active - 3 sets of 10 reps
Begin with your arms crossed in front of your chest. While keeping your elbows at your side, roll your arms out. Hold at your limit for 0 seconds. Relax and return to the starting position. Repeat 10 times. Sets: 3

7. Biceps Curl, with Elastic - 3 sets of 10 reps
Hold one end of the elastic, attach the other end safely to your foot. Bend your elbow against the elastic. Return to the starting position, slowly. Repeat 10 times. Sets: 3

8. Elbow Extension - 3 sets of 10 reps
Lie on your back on a firm surface. Touch your hand to opposite shoulder. Your elbow should point to the ceiling. Raise hand up toward the ceiling until your elbow is straight. Slowly lower your hand to the starting position. Repeat 10 times. Sets: 3

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Appendix C
Contains Proper Skin Care for Lower Extremity Amputees
Here is what should be done every evening to keep your skin in good condition.

1. Wash your stump with mild soap and lukewarm water.

2. Rinse thoroughly with clean water. Be sure to remove all the soap as it may irritate your skin. Do not soak for long periods of time as this may soften your skin and cause swelling.

3. Dry skin thoroughly. Avoid brisk rubbing which may irritate your skin.

DO:
- Gently massage and handle your stump several times a day. This will help decrease sensitivity and increase tolerance to pressure.

DO NOT:
- Shave the stump as this will irritate your skin and cause an itchy rash.
- Apply lotions, creams, or moisturizers to your skin.
Appendix D
Contains Information on Lower Extremity Exercises
POSITIONING

The following postures are recommended in order to keep your stump fully mobile. Keep your elastic bandages on while assuming these positions.

1. Backlying:
Whenever you are lying on your back, assume this posture.
- Lie on a firm surface.
- Avoid pillows under your stump.
- Keep your stump flat on the bed with the knee straight.
- Keep your legs close together.

2. Facelying:
Whenever you are lying on your stomach, assume this posture.
- Lie on a firm surface.
- Keep your hips flat on the surface.
- Keep your knees straight.
- Keep your legs close together.

3. Sitting:
Avoid prolonged periods of sitting. While sitting, assume this posture.
- Sit on a firm surface.
- Sit up straight with weight on both hips.
- Support the stump on another firm surface.
- Keep your knees straight.
- Avoid crossing your legs.

...
EXERCISE

To maintain or increase muscle strength and flexibility, do the exercises checked by your therapist.

Remove your elastic bandages while exercising. It is important to breathe normally while doing these exercises.

1. Hip Flexion
   - Bend your knee on the amputated side toward your chest.
   - Keep your other leg flat on the mat.
   - Straighten the bent knee as you lower your leg to the mat.
   - Relax.
   - Repeat the exercise \( \frac{1}{3} \) times.

2. Straight Leg Raising
   - Keeping the knee straight on the amputated side, lift your stump toward the ceiling.
   - Keep your other leg flat on the mat.
   - Lower the stump to the mat.
   - Do not allow the knee to bend while lifting or lowering.
   - Relax.
   - Repeat the exercise \( \frac{1}{3} \) times.

3. Hip Extension from Thomas Position
   - Begin with both legs bent toward your chest.
   - Using your hands, hold your non-amputated leg tightly against your chest.
   - Lower your stump toward the mat.
   - Push your stump down into the mat while keeping the knee straight.
   - Hold for 5 counts.
   - Relax.
   - Repeat the exercise \( \frac{1}{3} \) times.
REMINDER: DO NOT HOLD YOUR BREATH

4. Isometric Hip Extension
Place a small towel roll under the end of your stump.
Press down into the towel until your buttocks lift off the mat.
Hold for 5 counts.
Relax.
Repeat the exercise ______ times.

5. Hip Abduction-Adduction
Place a towel roll between your thighs.
Move your stump away from the other leg as far as possible.
Be sure the knee faces the ceiling at all times.
Pull the stump in toward the other leg and squeeze the towel roll.
Hold for 5 counts.
Relax.
Repeat the exercise ______ times.

6. Isometric Abduction-Adduction
Place a small towel roll between your thighs.
Tie your legs together with a strap at least 2 inches wide.
Try to push your legs apart.
Hold for 5 counts.
Now squeeze the towel with both legs.
Hold for 5 counts.
Relax.
Repeat the exercise ______ times.

7. Quadriceps Setting
Tighten your thigh muscle on the amputated side by flattening the knee against the mat.
The kneecap will move slightly upward.
Hold for 5 counts.
Relax.
Repeat the exercise ______ times.
REMINDER: DO NOT HOLD YOUR BREATH

☐ 8. Hip Extension with Knee Flexion
   Bend your knee on the amputated side and place your legs close together.
   Lift your thigh off the mat while keeping your hips flat on the mat.
   Hold for 5 counts.
   Relax.
   Repeat the exercise ___ times.

☐ 9. Hip Extension With Knee Extension
   Begin with straight knees and legs close together.
   Lift your stump off the mat while keeping the knee straight.
   Keep your hips flat on the mat.
   Hold for 5 counts.
   Relax.
   Repeat the exercise ___ times.

☐ 10. Gluteal Setting
    Squeeze your buttocks together.
    Hold for 5 counts.
    Relax.
    Repeat the exercise ___ times.
REMINDER: DO NOT HOLD YOUR BREATH

11. Knee Flexion
Begin with straight knees and legs close together.
Keep your hips flat on the mat as you bend your knee on the amputated side.
Bend your knee as far as possible and hold for 5 counts.
Relax.
Repeat the exercise ___ times.

12. Hip Abduction
Lift your top leg toward the ceiling.
Keep your knee facing forward.
Do not allow your hips to roll forward or backward.
Hold your leg up for 5 counts.
Relax.
Repeat the exercise ___ times.

13. Hip Extension
Push your top leg backward.
Keep your knee straight and facing forward.
Do not allow your hips to roll forward or backward.
Hold for 5 counts.
Relax.
Repeat the exercise ___ times.
1. Knee Extension
   Sit on a firm surface.
   Sit up straight with your weight on both hips.
   Keep your thigh in contact with the surface as you straighten your knee.
   Hold for 5 counts.
   Relax.
   Repeat the exercise ___ times.

1. If Using A Walker:
   Inspect your walker to be sure it is safe for use. Check the tips for signs of wear. The legs of the walker should all be the same height.
   Keep your stump close to the other leg and pointed toward the floor.
   Keep your knee straight.
   Do not rest your stump on the cross bars of the walker.