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TRANSFEMORAL AMPUTATION AND PHYSIOTHERAPY: A TOOL KIT FOR PRACTICE

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REISIAMPUTAATIO JA FYSIOTERAPIA: OPAS FYSIOTERAPEUTEILLE

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Tämän tutkielman tarkoituksena oli koota reisiamputaatiota käsittelevä tietopaketti, jota fysioterapeutit voivat käyttää hoitaessaan reisiamputaatiopotilaita ja jota voi käyttää myös johdantona jatko-opintoihin. Nämä päämäärät mielessä pitäen määriteltiin hakusanat, joilla tehtiin hakuja esimerkiksi PubMed-, Pedro-, Cochrane- ja Ovid-tietokannoissa.

Hauilla löytyi useita artikkeleita, joista 208 valittiin. Lähdekirjallisuuden valintakriteereinä olivat materiaalin keskeisyys ja julkaisuvuosi (vuoden 1990 jälkeen julkaistut artikkelit hyväksyttiin). Valittujen artikkeleiden yhteenvedot luettiin ja 57 artikkelia otettiin tarkempaan tarkasteluun. Artikkeleita, jotka käsittelevät näyttöön perustuvaa reisiamputoitujen fysioterapiaa, oli todella vaikea löytää. Lähdeaineiston löytämisen vaikeus paljasti tarpeen tuottaa enemmän tutkimuksia amputaatiopotilaiden fysioterapiasta.

Tarkoituksena on ollut läpi tutkielman säilyttää kappaleiden välillä looginen jatkumo, joka auttaa lukijaa näkemään asioiden väliset suhteet ja tekemään toimivan hoitosuunnitelman. Tutkielman alussa esiteltiin lyhyesti leikkaustekniikkaa, leikkauksen jälkeisiä mahdollisia komplikaatioita, tynkää ja biomekaanisia muutoksia. Sitten käsiteltiin reisiproteesia, reisiamputaatiopotilaiden fysioterapiaa ja lopuksi amputaatiopotilailla esiintyviä muutoksia kävelemisessä.

Tutkielman tavoite täyttyi: se tarjoaa teoreettista tietoa reisiamputaatiosta ja reisiproteesista sekä näyttöön perustuvia periaatteita reisiamputaatiopotilaiden kuntoutuksen suunnitteluun.

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The purpose of this thesis was to collect a package of information related to transfemoral amputation that could act as a tool kit for physiotherapy management of the individuals with amputation at transfemoral level and that could be used as an initial guidance towards further studies. With these goals in mind a set of search terms was defined and several databases such as PubMed, Pedro, Cochrane, and Ovid were searched.

Searches yielded many articles among which 208 articles were selected. The inclusion criteria for selecting the study literature were the relevance of the material with the study topic and being newer than 1990. The abstract of these articles were read and 57 articles were selected for further studying. Finding articles related to the evidence based practice of physiotherapy for transfemoral amputees was very difficult. This revealed the need for the production of more studies in the physiotherapy of amputee clients.

Throughout of this thesis the aim has been to keep an organic relation between different chapters in order to enable the readers of this work to realize the relationships and therefore to create their treatment plans better. At first the surgery technique, complications of the surgery, residual limb, and biomechanical changes were shortly explained. Then transfemoral prosthetic limb, physiotherapy rehabilitation of transfemoral amputees, and finally gait deviations among amputees were explained.

This thesis was able to reach its goals through providing theoretical information about the transfemoral amputation and transfemoral prosthesis and through providing a set of evidence based guidelines for physiotherapeutic rehabilitation of the individuals with this level of amputation.

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1 INTRODUCTION

Every year hundreds of thousands of lower limbs are amputated around the world (Ziegler-Graham, MacKenzie, Ephraim, Travison & Brookmeyer 2008). The number of amputations in Finland also reaches several hundreds every year (Eskelinen et al. 2004, 193-200). Regardless of the etiology, amputation is physically and psychologically stressful experience (Atherton & Robertson 2006). One feature of life with limb loss that makes it physically stressful experience is related to the amount of the energy consumed during prosthetic limb gait. Studies show that there is a relation between the level of the amputation and the amount of the energy required for ambulating with prosthetic limb and with assistive devices (Waters & Mulroy 1999, 207-231).

The rehabilitation of transfemoral amputees is a transdisciplinary process aiming at enabling amputees to achieve the highest level of daily life functioning. During this process physiotherapy and physiotherapists are of valuable help to amputee's physical condition and gait education. Improving their knowledge of amputation, prosthesis and prosthetic limb gait physiotherapists can be of greater help. (Carroll & Edelstein 2006, 15)

This tool kit is a review of the literature related to the physiotherapeutic rehabilitation of the transfemoral amputees. This work is based on the related evidence based guidelines and practices. Search for data initiated by defining a set of search terms which included amputation, amputee, amput, physiotherapy, physio, rehabilitation, rehab, transfemoral and other relevant terms. Different databases and collections such as PubMed, Pedro, Cochrane, Ovid, and Google books were investigated that brought forward a big number of articles. The articles for this study were selected based on their relevance with the topic and being newer than 1990. Through this method of data collection, different research reports (journals), books, internet publications, hospital treatment guides, service catalogs, and product catalogs were selected for compiling this work. At the end, 57 articles were selected that were classified in amputation, prosthesis, physiotherapy, and biomechanics groups. The search process showed that finding evidence based literature related to physiotherapy practice among amputees is very difficult. Therefore, physiotherapists are encouraged to conduct researches in this area.

This tool kit starts with amputation surgery and continues with prosthetic management, and finally physiotherapy rehabilitation of the individuals with limb loss. Efforts have been made to keep a systematic relation between different chapters of this work. Therefore, while reading through this guide little by little the bigger picture of physiotherapy management and amputee rehabilitation is formed. It should be notified that this guide is not intended to teach a specific treatment or set of exercises.

2 AIMS

The aim of this study is to provide a set of guidelines that physiotherapists can use for planning rehabilitation programs for transfemoral amputees and to make physiotherapists familiar with different aspects of amputation.

3 ETIOLOGY AND PREVALENCE

Major reasons for amputating a limb are peripheral vascular diseases (PVD), diabetes, trauma, tumor and congenital limb deformities (Eskelinen et al. 2004, 193-200). Among these etiologies, vascular diseases and diabetes are responsible for most of the amputations (Apelqvist & Larsson 2000). PVD is frequently companied with the symptoms such as pain, numbness, tingling, cold feelings in the lower extremity and feet. Pain in leg comes with walking and disappears when person stops the activity (claudication symptom). At one point, patient starts to develop persistent ulcers on the involved leg. In the advanced and untreated stages of PVD, the ischemic tissues can die. The necrotic tissue eventually becomes infected with germs and gangrene happens that requires amputation of the limb. (Society of Interventional Radiology 2008) Vascular diseases have been responsible for 82% of all the amputations (Dillingham et al. 2002) and 89.4% (Eskelinen et al. 2004, 193-200) to 97% (Dillingham et al. 2002) of all the lower-limb amputations.

Diabetes increases the amount of glucose in blood circulation and creates a condition named hyperglycemia. Prolonged exposure to hyperglycemia is recognized as a major factor in the pathogenesis of atherosclerosis in diabetic patients (Aronson & Rayfield 2002). Hyperglycemia is also considered responsible for peripheral neuropathy in diabetic patients (Porte, Sherwin, Baron, Ellenberg & Rifkin 2002, 771-775). The presence of the sensory dysfunction exposes diabetic patients to traumatic and infectious wounds. Dysfunction in blood circulation which is caused by atherosclerosis prolongs the healing process. These diabetic wounds (ulcers) in some cases never heal and little by little cause the tissue to gangrene. When this happens, the amputation of a body part would be indicated (Porte et al. 2002, 895-897). According to Eskelinen et al (2004, 193-200), 48% of the vascular problems leading to lower-limb amputation have had diabetes mellitus as a predisposing factor. Another study shows that a big number of lower extremity amputations, 40-60%, happen as a consequence of diabetes (Apelqvist & Larsson 2000).

Physical trauma through crush, guillotine and avulsion mechanisms causes limb-threatening injuries. Crush injuries are due to the compressing forces that can cause multiple fractures in bones along with vast damages to muscles and neurovascular structures. Guillotine injuries happen when a body part is caught between two sharp parts. Avulsion injuries happen when a body part is grabbed between two objects that forcefully pull the limb and detach it from body (Murphy, Colwell, Pineda & Bryan 2006). In Finland, the number of the trauma-related amputations has decreased from 12% of all amputations in the year 1970 to 4% in 1995 (Eskelinen 2005). In the year 2000 only 1.6% of the major lower limb amputations have been due to trauma (Eskelinen et al. 2004, 193-200). Similarly, in the USA the number of the trauma-related amputations declined from 11.37 per 100,000 persons in 1988 to 5.86 per 100,000 persons in 1996 (Dillingham et al. 2002). In connection with gender, the number of trauma-related amputations has been significantly higher among men than women, with an incidence rate ratio of 4.94 (Dillingham et al. 2002). Kulkarni et al (2005) calculated a figure of 86.14% as the percentage of trauma-related lower-extremity male amputees (Kulkarni et al. 2005).

Generally, the number of amputations caused by different etiologies is decreasing. In the year 2000 the incidence rate for major amputations in Southern Finland has been 154 per million inhabitants which is 25% less than the figures for the year 1990. About 87.7% of these amputations, 135 per million inhabitants, were major lower-limb amputations. The below-knee/above-knee ratio was 0.76, which gives a sum of 102.6 per million inhabitants as transfemoral amputees. With regard to patients' age, transfemoral amputees have been older than below-knee amputees. The study also demonstrates that the mortality rate during the first year post-amputation was high among those who had transfemoral amputation (60.8%) compared with below-knee amputees (38.9%). At the end of the first year, 68% of the below-knee amputees and 19% of the above-knee amputees had been fitted with prosthesis. (Eskelinen et al. 2004, 193-200)

4 AMPUTATION

It is generally accepted that amputations should be done at the most distal site where wound healing can happen and is suitable with regards to prosthetic fitting and rehabilitation (Hunter 1996, 239-246). One important issue related to the level of amputation is the energy costs of the prosthetic limb gait. Amputation at higher level requires more energy during ambulation in comparison with ambulation at lover levels (Waters & Mulroy 1999, 207-231).

Often, during surgery, the major blood vessels are cut at the same level where the bone is transected; nerves are cut at a level 2-4cm shorter than bone; muscles and periosteum are transected such that their length is a little longer than the length of the residual bone. If possible the quadriceps is cut just proximal to patella so it would retain some of its tendon. Adductor magnus is not only detached from the adductor tubercle but also from linea aspera. And finally, femur is transected 7.5-10cm proximal to the knee joint line. This depends on the nature of the problem because sometimes the limb is cut at a higher level. Some drill holes are made on the external surface of the distal end of the residual femur. These are used for re-attaching muscles to bone. (Gottschalk 1992)

One important aspect of the transfemoral amputation is suturing and fixing muscles on the residual bone. Usually adductor magnus tendon is attached to the lateral aspect of the distal end of the residual bone. For this purpose it is brought around the distal femur and sutured to bone through drill holes (myodesis), approximately 5-6cm from the distal edge of the bone. This is done while keeping femur in full adduction. The goal is to keep the hip joint in full adduction posture for a better postoperative rehabilitation. Furthermore, the strength of the adductor magnus is needed for overcoming the pulling force of the abductor muscles (that often remain intact). Once done with adductor magnus, the quadriceps is anchored to the posterior aspect of femur through some drill holes. While doing this, hip joint should be in extension to prevent hip flexion contracture. After that, hamstrings are re-attached to the posterior area of the adductor magnus. (Gottschalk 1992)

Amputation surgery might have some complications such as formation of neuroma, formation of bony prominences, contracture in muscles, delay in healing, skin adherence to bone, edema, and phantom sensation/pain. In this list contracture in muscles, edema, and phantom pain (to some extent) are the complications that physiotherapists are expected to find a treatment for. (Bowker, Keagy & Poonekar 1992)

Muscle contracture can occur with flexion or abduction pattern. As far as the surgery technique is concerned, the contracture can happen because of a mistake in securing thigh muscles on the residual bone. Surgeons are supposed to keep residual limb in full adduction and extension while thigh muscles are re-attached. Muscle contracture can be also due to the mal-handling of the stump during postoperative care. Patients, physiotherapists, and care givers are instructed to not use any pillow under the stump while patient is in lying position. Patients are instructed to not keep sitting posture (with hip joint in flexion) for long time. (Bowker, Keagy & Poonekar 1992)

Residual limb edema is a complication experienced by almost every amputee after surgery. In some cases edema can be seen even 6-8 months post-amputation. Edema can complicate the wound; cause pain; postpone prosthetic fitting; and postpone healing process (Bowker, Keagy & Poonekar 1992).

Phantom limb sensation is experienced by 66.8% (Wartan, Hamann, Wedley & McColl 1997, 652-659) to 79% (Ehde et al. 2000) of amputees. These figures are big and therefore, physiotherapists should assure their amputee clients that these sensations are very common. Furthermore, different sensations such as; numbness, tingling, muscle cramp, temperature changes, movement, weight, or pressure in the missing limb (Seymour 2002, 45-49) have been reported. Researchers consider a discrepancy in the body image as the reason why these sensations are felt (Zuckweiler & Kaas 2005). Zuckweiler believes that there is a conflict between the body image that is preserved in the amputee's neural system and the changed shape of the body. Zuckweiler even has developed a method (Zuckweiler's Image Imprinting) through which she tries to verify amputee's body image in order to make it match the present shape (Zuckweiler & Kaas 2005).

Phantom limb pain is experienced by 72% (Ehde et al. 2000) to 79.9% (Ephraim et al. 2005) of amputees. Some studies suggest that higher level of prosthesis satisfaction is significantly correlated with fewer pain categories reported by amputees. The less phantom pain is felt the more satisfaction is expressed. This correlation is stronger among men compared with women (Murray & Fox 2002).

Different medical and psychological methods have been suggested for treating phantom limb pain. Most of these treatments, such as using local anesthetic agents and transcutaneous electrical nerve stimulation (TENS), only provide a temporary relief from pain (Schnell & Bunch 1992). Pain returns at another time. There are also other treatments such as Zuckweiler's Image Imprinting (Zuckweiler & Kaas 2005) that are clamed to be of longer effect.

5 BIOMECHANIC CONSIDERATIONS

When transfemoral amputation is required, it is recommended to transect femur from just below the insertion of adductor magnus to preserve this muscle's adduction force. But femur is usually transected at 7.5 to 10 cm above the line of knee joint except if the nature of the disease or trauma demands amputation at a higher level. Amputation at this level causes sartorius, semitendinosus, semimembranosus, biceps femoris, tensor fascia lata, adductor magnus, rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis to lose their natural insertion. These muscles are then sutured either to bone or to each other. (Gottschalk 1992)

The structural changes that come with amputation, affects body in different ways. Perhaps the direct effects should be expected to happen in weight bearing, hip joint, the stability of pelvis girdle, vertebral alignment, and intact leg alignment. The effect of transfemoral amputation on weight bearing is immediate and very obvious, bipedal weight bearing all of a sudden becomes unipedal. To verify the condition later on during rehabilitation process prosthetic limbs are prescribed but it is hard to compare weight bearing through bone to weight bearing through skin and soft tissue. (Gottschalk 1992)

Other obvious and immediate changes happen in thigh muscles. Due to these changes the properties and consequently the function of the residual muscles are affected. The first reason for the changes is that the amputated muscle would have new insertion point which is at more proximal location than before. In other words, in the new lever that is formed though the load (resistance) arm is shorter (a big portion of the leg is removed), the effort arm is also shorter than before (the new insertion is at a more proximal location and therefore the lever arm is shorter). The second reason is that the new proximal insertion makes the angle between muscle's pulling line and horizontal line smaller. The third reason is that muscle losses some part of its mass. This presumably causes the residual muscle to generate less force than before. And the forth reason is that muscle's pulling force is not applied to bone via tendon because in many cases, during amputation surgery, tendon is removed. (Gottschalk 1992)

Bone and muscular changes affect the stability of hip joint and therefore the stability of pelvis girdle. This issue can be studied from different perspectives including muscles structure (dynamic stability) and passive forces (gravity force). Insufficient stability of pelvis, on the other hand, makes amputees vulnerable to further physical problems. (Gottschalk 1992)

5.1 Hip joint in sagittal and frontal planes

Due to the reasons discussed in the previous paragraphs, transfemoral amputation makes some of the muscle groups functioning on the hip joint to have mechanical disadvantage (smaller moment) compared with their antagonists (Schuch 1992). This means that a given residual muscle due to the smaller lever arm needs to consume more energy than before in order to generate the same amount of stabilizing and rotational forces (torque) as before. Figure 5.1 demonstrates this phenomenon when it happens to adductor magnus (AM) after amputation. In this figure the angle between AM's pulling line and the torque vector is smaller in the amputated AM (b^{o}) in comparison with the intact AM (a^{o}). This hypothesis theoretically sounds correct though it is difficult to know if it is practically proven or not. This is because all the researches related to the energy expenditure in amputees are related to the amputee's gait with prosthetic limb. (Schuch 1992)

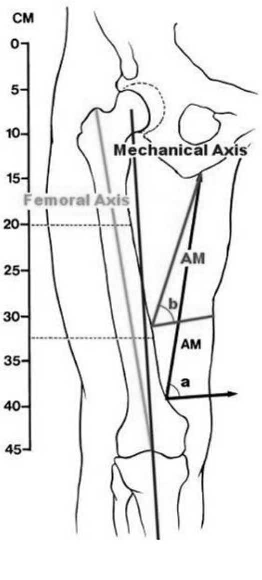

Figure 5.1. Mechanical disadvantage of residual muscles. In this figure amputated adductor magnus (red color) possess a more proximal insertion compared with the time when the muscle is intact and b^{o} < a^{o}. (Schuch 1992)

As a result of the mechanical disadvantage, the risk of muscular contracture increases. An instance of this condition is when femur is amputated higher than the insertion of the adductor magnus. In this case, especially if parts of the muscle are also amputated, the adductor group losses a big percentage of its force. In one source, adductor magnus is considered to provide 70% of the adduction force (Gottschalk & Stills 1994). The higher the amputation level, the weaker the adduction force becomes. At the same time, in most transfemoral amputations the major hip abductor (gluteus medius) remains intact. This condition can lead to abduction contracture of the hip joint (frontal plane deformity). (Schuch 1992)

One more advantage that hip abductors for example gluteus medius have over hip adductors is derived from the fact that the normal anatomic alignment of the femoral shaft is in adduction. Indeed, in anatomical bipedal stance femoral axis makes about 9º of adduction (Schuch 1992) with sagittal plane. When lower limb is intact, this position prevents lateral instability of the pelvis. When the leg is amputated and is not anymore in a kinetic closed chain with earth and if adductor muscles are not attached properly to residual femur then the strength of abductors can pull the residual limb to abduction position which contributes to the abduction contracture. (Schuch 1992)

According to Schuch (1992) a similar muscle contracture can occur in the sagittal plane, where flexion and extension of the hip joint are performed. The location of muscle insertion points has made hip flexors to have better mechanical advantage when compared with extensor muscles. This can led to flexion contracture and consequently causes anterior rotation of pelvis and hyper lordosis of lumbar vertebra when the amputee is fitted with a prosthetic limb. Furthermore, muscle weakness among hip extensors can contribute in the hip flexion contracture. In one research gluteus maximus muscle of the unilateral transfemoral amputees has been studied. The researchers have noticed a displacement in the muscle belly that according to them is a sign of muscle atrophy and weakness (Burger, Valenčič, Marinček & Kogovšek 1996, 35-38). In connection with hip extension limitation, one study shows that one year after amputation at least 42% of elderly amputees (>60 years of age) had limited hip extension (Schoppen et al. 2002).

5.2 Pelvis in sagittal and frontal planes

Unsupported unipedal creates a condition in which the line of gravity has the tendency of falling off the normal alignment and therefore the effective center of gravity would have the tendency of moving distally and away from the supporting leg (in the frontal plane). In such a situation there are three strategies for keeping the body from falling. (Schuch 1992; Tampson 2001)

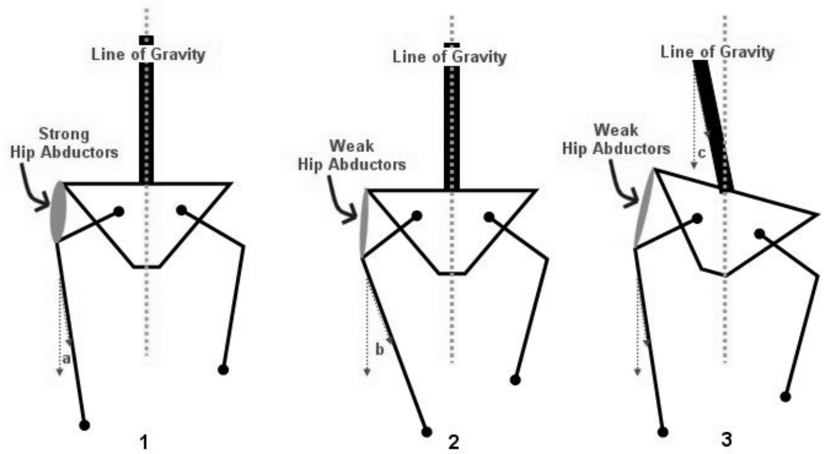

Figure 5.2. Three possible strategies adapted by amputees for preventing falls while standing without prosthesis

Figure 5.2 depicts these possibilities. Number 1 in this figure describes a situation in which the amputee has strong hip abductors (strong tensor fasciae lata and gluteus medius) in the sound limb. In this case strong hip abductors resist against the vertical force (body weight) which wants to tilt pelvis and line of gravity towards the amputated limb. In number 2, hip abductors are weak or over used and therefore unable to keep pelvis in symmetrical position. To resist the vertical force of body weight and keep the line of gravity in the base of support amputee adducts the hip joint to the maximum degree ($b^o > a^o$). This is done so hip adduction would be limited by its structural limits and therefore the strong ligaments would pull up the pelvis (towards the supporting limb) and provide stability. In addition to that, hip abductors would reach their maximum length and therefore provide some muscular force. In number 3, weak hip abductors are unable to prevent the center of gravity from dropping towards the amputated leg and therefore unable of preventing pelvis from tilting. To prevent a fall, amputee bends his/her trunk towards the stance leg (positive Trendelenburg sign). (Schuch 1992; Tampson 2001)

On the other hand, as the normal alignment of the line of gravity passes posterior to the axis of the hip joint it creates a torque with the tendency of hyper extending hip joint (Tampson 2001). In anatomical bipedal standing no muscular function is required to resist the torque as far as legs are in closed kinetic chain with a supporting surface. In this case the passive tension in strong iliofemoral ligaments prevents the posterior rotation of pelvis and hyper extension of the hip joint (Guilak et al. 2002). The condition for transfemoral amputees is complicated by the fact that in the unipedal standing only the iliofemoral ligament of the intact leg is opposing the torque. As the possible result of this situation, the hip joint of the residual limb is pulled towards flexion. Indeed, in the absence of the opposing force of iliofemoral ligament, pelvis is tilted posteriorly and consequently iliofemoral ligament pulls residual limb towards flexion. This situation contributes in flexion contracture that happens after some transfemoral amputations. (Schuch 1992; Tampson 2001)

6 TRANSFEMORAL PROSTHESIS

Socket, suspension method, knee mechanism, and ankle/foot mechanism are the prosthetic limb components usually discussed in the literature. Socket is a part of the prosthesis in which the residual limb is placed. Socket holds the residual limb tightly and is a mean for connecting the rest of the prosthesis to amputee’s body. Suspension method is one of a few methods by which socket is kept in intimate contact with body. Knee and ankle/foot mechanisms are devices that replicate the function of these joints. According to Broomhead et al (2003) it is essential for physiotherapists to have sufficient knowledge about prosthetic design, components and functions to ensure the safe usage of the prosthetic limbs. (Broomhead et al. 2003)

6.1 Biomechanics of knee stability

The ability of the prosthetic knee to remain extended and completely supportive during the stance phase of gait is considered knee stability or knee control.

Concluding from this definition the prosthetic knee instability can be considered any unwanted flexion and giving way throughout the stance phase. On the other hand, excessive stability of the knee component makes it difficult for the user to properly flex the knee at toe-off phase of gait. This condition causes an unnatural swing phase and excessive consumption of energy. (Schuch 1992)

Prosthetic knee control happens through involuntary control and voluntary control mechanisms (Schuch 1992). In some prostheses, involuntary knee control occurs because of the alignment of the prosthetic limb. In this case knee axis is located posterior to the weight line (figure 6.1 C). At heel strike when heel touches the ground the torque that is created has the tendency of plantar flexing ankle/foot component and flexing the knee joint. But on the other hand because knee is already in extension and the location of the knee axis is posterior to the weight line then knee is strongly maintained in extension and no flexion happens. Furthermore, during the rest of the stance phase (from mid stance through toe-off) when body weight is placed on the prosthetic foot this arrangement forces the knee component into extension. This stability is not achieved and maintained through active use of hip extensors and that is why it is considered involuntary stability. The alignment stability sometimes can be explained by comparing the positions of the knee axis in relation to the position of socket and ankle/foot components. (Schuch 1992)

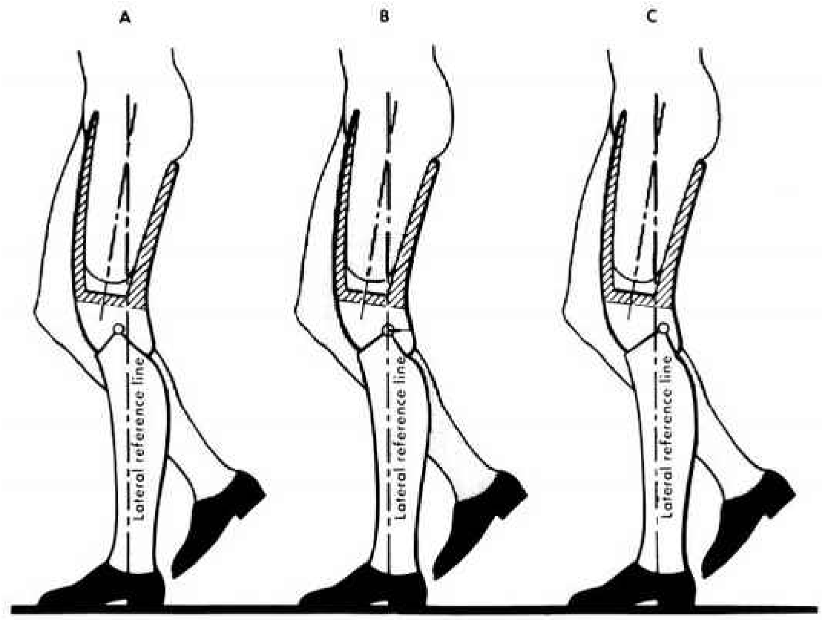

Figure 6.1. A, knee axis is placed anterior to the laterally-viewed weight line. B, knee axis is placed exactly on the weight line. C, knee axis is placed posterior to the weight line. (Schuch 1992)

On the other hand, voluntary knee stability (or control) means that the stability is achieved and maintained via active usage of the hip extensors (Schuch 1992). In some prostheses (figure 6.1 A & B), the axis of the knee joint is located either anterior to the weight line (A) or exactly on the weight line (B). The torque that is created due to the heel strike causes both plantar flexion in ankle/foot component and flexion in knee component. To prevent excessive flexion of the knee component and to maintain control over the joint's movement amputee uses hip extensors actively to pull the knee joint again into extension. In figure 6.1 the tendency of knee flexion in sample A is more than sample B. In sample A knee joint is actively controlled for the rest of the stance phase (from mid stance until toe-off) while sample B provides some involuntary (or alignment) stability during mid stance and toe-off phases. For amputees with stronger muscles voluntary knee stability can provide smoother and more energy efficient gait (Schuch 1992).

6.2 Biomechanics of pelvis stability

During bipedal stance and in the presence of the inefficient pelvis stabilizers pelvis and trunk become laterally instable (chapter 5.2). This is usually seen as positive Trendelenburg sign. A typical compensatory response to this situation is by widening the base of support and therefore causing wide-based gait (Schuch 1992). To provide some lateral stability in pelvis and therefore narrowing the width of walking, femur should be kept in a position as close as possible to normal. To achieve this initial adduction, sockets are designed and aligned such that the lateral wall of socket inclines medially to position the stump in about 10º of adduction (May 2002, 141). There are other factors that affect the lateral stability of pelvis as well. Some of them are length of residual limb, proper alignment of the components below the socket, and the mass of tissue in the residual limb (Schuch 1992).

6.3 Transfemoral socket

Many amputees take socket and how well it fits the residual limb as their first major concern (Legro et al. 1999). With regard to the type of sockets quadrilateral, ischial containment, and contoured ischial containment are commonly used. Quadrilateral socket is composed of 4 distinct walls. The posterior wall is thick and most of the weight bearing is achieved through it specially the top part where ischial tuberosity and gluteal muscles sit up. The wall is contoured to make a relief for hamstrings. Anterior wall stands about 5 cm higher than the posterior wall and it is contoured to provide relief for rectus femoris muscle. Anterior wall gently presses the residual limb against posterior wall in order to keep ischium sited up on top of the back wall. Lateral wall has the same height as anterior wall in order to briefly limit hip abduction. It inclines medially to provide an initial adduction for the stump. Medial wall is contoured to provide relief for adductor muscles. (May 2002, 141)

The ischial containment socket was designed to improve pelvis stability during stance phase; to provide comfortable weight bearing; and to make the swing phase smoother. In this socket ischium and ascending ramus are enclosed inside the socket. This contributes with distribution of weight over a larger area (May 2002, 141-142). Indeed, residual limb is tipped inward in order to transfer some of the weight to the lateral wall (Smith 2004). The lateral wall is high enough to enclose the greater trochanter within the socket and this provides more medio-lateral stability for pelvis during stance phase (May 2002, 141-142).

Countered ischial containment socket basically follows the same idea as the previous socket design except that in this one the socket is countered for all the muscle compartments. The goal of designing this socket has been to increase the medio-lateral stability of the residual limb within socket and to encourage the use of the residual muscles. (May 2002, 142)

6.4 Suspension methods

Using a suspension method prosthetic limb remains attached to the residual limb. If prosthesis is not suspended properly it interferes unfavorably with gait. Some common methods of suspension are suction, shuttle lock system, silesian bandage, total elastic suspension, and pelvic belt. (May 2002, 137-148)

Suction method functions based on the negative pressure that is created during the donning process. When residual limb is pushed into the socket, air is pumped out through a valve that is located at the bottom of the socket. This negative pressure holds the socket intimately on the residual limb (Smith 2004). This socket is worn either directly on the skin or on a silicon/gel liner (Haberman 1995). For wearing a suction socket using stockinet amputee should, wear stockinet on the residual limb; place the residual limb into the socket and put the free end of the stockinet out of the valve; stand up and push the residual limb deeper into the socket; pull the free end of the stockinet out of the valve while residual limb is bearing some weight; and finally secure the valve in order to block the air from reentering the socket. Some gel liners have a layer of fabric on their outer surface that makes it easy to don the socket. (Kahle 2001)

Shuttle lock system consists of a pin that is attached to the tip of a gel or silicon liner and a receptacle that is built into the bottom part of the socket. When amputee places the residual limb into the socket and bears some weight on it the pin enters the receptacle and engages with the locking system. Furthermore, the liner itself is also in intimate contact with socket that gives some extra suspension. In this way a proper attachment of socket to the residual limb is guaranteed. (May 2002, 137-138)

Other methods of suspension are primarily made of straps as in silesian bandage or belts as in pelvic belt. These methods are used with suction suspension method or in the case of the pelvic belt can be used as the main suspension system. In silesian bandage a strap that is attached to the lateral wall goes around pelvis and connects with the strap that is attached to the anterior wall. In pelvic belt one leather belt that is attached to the top of the lateral wall suspends the prosthesis when it is fastened around the waist. (May 2002, 145-148)

6.5 Prosthetic knee

Controlling the movements of the knee joint during stance and swing phases is important for having confidence during prosthetic gait (May 2002, 150). Stance phase control is determined by the mechanism through which different components of prosthesis function and the alignment of the prosthesis. During the stance phase the alignment of the prosthesis which is the position of the knee joint in relation with weight line can determine the amount of involuntary (known as alignment control as well) and voluntary stability of the knee component (Schuch 1992).

Swing phase control occurs in accordance with timing of the swing and swing tracking. If prosthesis is aligned such that it creates so much involuntary stability then a big amount of energy and effort is needed to flex the knee in order to initiate toe-off. This can cause a delay in toe-off and therefore interfering with gait. On the other hand, tracking is about how smooth the swing motion happens in the prosthetic shank and foot. Any unplanned vertical and sagittal plane movement interferes with the smoothness of swing phase. Inadequate suspension and inappropriate length of the prosthetic limb can led to unwanted vertical displacement. In sagittal plane the disturbing movements can be due to the inappropriate length of prosthesis, problem with the socket shape, and problem with the knee axis alignment. Accordingly, any attempt to control the timing of the swing phase initiation and control the track of the motion path can be named as swing phase control or stability. (Schuch 1992)

Along with prosthetic limb alignment, knee mechanism plays an important rule in the stability or control of stance and swing phases of prosthetic gait. There are several knee mechanisms commonly used, one of which is Single Axis knee. In this knee after adjusting the amount of friction the speed of knee flexion and extension remains the same regardless of the speed of gait (May 2002, 150). This mechanism provides only swing phase control and therefore stance phase should be controlled using the alignment of the prosthetic limb (Schuch 1992).

Polycentric Axis knee is another knee mechanism. The four-bar linkage used in this mechanism provides continuous displacement of the center of rotation according to the degree of flexion and extension of the knee. This arrangement emphasizes stability at heel strike and stance phase while decreases the stability at toe-off to provide an easy start of swing phase. Amputees with short residual limb and those with weak hip extensors (Schuch 1992) can be candidates for using this knee mechanism but not active walkers or athletes (May 2002, 151).

Weight Activated knee is another knee mechanism in which a braking system is implanted. The braking system is activated when body weight is transferred to the prosthetic limb at heel strike. The amount of weight needed for activating the brake and the degree of the knee flexion in which the brake is activated are adjustable based on amputee's weight, level of activity, and the amount of stance control needed (Schuch 1992). This knee is useful for the amputees who walk often at home; their speed of gait does not change; and usually walk on level grounds (May 2002, 151).

Manual Locking knee is another mechanism that as the name implies consists of a locking system. The lock can be manually engaged for walking or disengaged for sitting. This knee provides the stance phase stability to maximum amount but initiating swing phase is not facilitated at all. It is occasionally used for bilateral amputees or very weak amputees. (May 2002, 151-152)

Pneumatic/hydraulic knee is another prosthetic knee which has an air-filled (pneumatic) or oil-filled (hydraulic) piston-cylinder mechanism implanted in it (figure A1 in the Appendix 1). In this mechanism, increasing or decreasing the amount of resistance against the flow of air/oil determines the amount of the knee stability during stance and swing phases. Proper adjustments can provide stability at the stance phase, knee flexion at the beginning of the swing phase, and smooth knee extension at the end of the swing phase. Knee extension is crucial for weight bearing and knee flexion is needed for swing. (Schuch 1992; May 2002, 152)

Microprocessor knee is another mechanism which is used along with pneumatic or hydraulic systems. The pneumatic or the hydraulic component of this knee operates according to the regulations dictated by a microchip. The chip collects data from different parts of the prosthesis and accordingly regulates the knee function. This knee enables the amputee to walk with different speeds and on uneven surfaces. (May 2002, 152)

6.6 Prosthetic foot/ankle

Foot/ankle components are expected to duplicate the ankle/subtalar joint movements;

to absorb the ground reaction force; to maintain a stable base of support during weight bearing; to enable walking on wider range of surfaces (even and uneven); to duplicate muscle function; to be cosmetic. (Kapp & Cummings 1992; May 2002, 124). Some of the commonly used foot/ankle components are as follows.

SACH foot, solid ankle cushion heel (SACH) foot, has no joint. This foot consists of a solid central part (keel), a wedge in the heel part which is made of sponge rubber (cushion), and an external cover made of foam rubber (figure A2 in the Appendix 2). At heel strike the rubber cushion is compressed and a movement resembling plantar flexion occurs. This foot does not duplicate dorsi flexion movement. (Kapp & Cummings 1992; May 2002, 124-125) Resistance to dorsi flexion is determined by the length of keel. The longer keel is the less dorsi flexion is permitted. Longer keel interferes with knee flexion that is needed at the end of stance phase in order to initiate swing phase. (Kapp & Cummings 1992)

Single axis foot provides a limited amount of joint movement. This foot has an axis with two rubber bumpers. The one in front is dorsi flexion bumper and the one in back is plantar flexion bumper (figure A3 in the Appendix 2). After heel touch, there is a sudden foot flat. This sudden movement increases knee extension moment and therefore provides some stability during stance phase. (Kapp & Cummings 1992; May 2002, 124-125)

Soft keel foot consists of a flexible keel which is surrounded by an elastic foam rubber (figure A4 in the Appendix 2). The heel area to a minimal amount allows inversion and eversion. This quality enables amputees to walk on uneven surfaces. (May 2002, 124-125) Soft keel feet are also considered dynamic response (or energy conserving) components due to the keel that function as a leaf spring. Indeed, during stance phase keel bends to absorbs energy. Later on at toe-off this energy is released to provide some push off. (May 2002, 124-125)

Multiaxial foot provides some dynamic respond and some degree of inversion and eversion movements. Some of these feet have rubber-made plantar and dorsi flexion bumpers. In addition to that, the keel part is composed of two leaf springs that are placed next to each other longitudinally to provide some adaptation to uneven surfaces. In the sample seen in figure A5 in the Appendix 2 ankle joint provide some degrees of rotation in transverse plane. (May 2002, 127-128)

7 PHYSIOTHERAPEUTIC REHABILITATION

Physiotherapists who treat individuals with limb loss should bear in mind that amputation is a physically and psychologically stressful experience with profound effects on the body image. Amputation is associated with sudden onset of anxiety and depression. These conditions are seen among 43.3-51.5% of the lower limb amputees. These feelings do not last long and it has been documented that after a period of rehabilitation there has been a rapid drop in these figures. (Atherton & Robertson 2006; Hanley et al. 2004; Singh, Hunter, & Philip 2007)

It is said that rehabilitation of the individuals with limb loss is a transdisciplinary process (Pasquina et al. 2006) and that the best prosthetic outcome is achieved through a multidisciplinary team work (Broomhead et al 2003). The ultimate goal of the rehabilitation process is empowering every amputee to return to daily life functioning at the highest achievable level based on his/her capabilities and goals (Carroll & Edelstein 2006, 15). In the ideal settings, this goal is achieved through team work. Such a team usually includes disciplines like surgeon, physiatrist, nurse, physiotherapist, occupational therapist, prosthetist, social worker, and mental health professional (May 2002, 12).

Throughout the rehabilitation process therapists follow a treatment protocol that is defined by rehabilitation team. Such a protocol is usually concerned with issues like surgical wound must be treated, pain must be minimized, residual limb should be protected from trauma, range of motion and strength of the entire body should be preserved and improved, swelling and edema should be reduced in order to facilitate proper shaping of residual limb, the use of appropriate mobility devices should be taught, functional abilities should be improved, psychological adjustment should be facilitated (Carroll & Edelstein 2006, 16). Physiotherapists should not focus their treatment on pathology or disease but on functional loss and disability of the amputee (Seymour 2002, 40).

In connection with rehabilitation of the individuals with limb loss the following 9 phases can be distinguished preoperative, amputation surgery/reconstruction, acute postoperative, preprosthetic, prosthetic prescription and fabrication, prosthetic training, community integration, vocational rehabilitation, and follow up. From the view point of physiotherapy practice preoperative, acute postoperative, preprosthetic, and prosthetic are the phases that require the involvement of physiotherapists. (Esquenazi 2004; Esquenazi & Meier 1996)

Whether in the inpatient setting or outpatient settings physiotherapists should gather sufficient information through assessment methods to be able to set the therapy goals. Assessments should include subjective and objective tests; and should consider patient's social status, dwelling environment, emotional and cognitive status. Assessment should have a holistic approach and should include different systems of body such as skin, musculoskeletal, neuromotor, and cardiovascular. Assessment should also include a functional evaluation tool for monitoring the effectiveness of the therapy. (Broomhead et al 2003)

Individuals with limb loss during different phases of their rehabilitation can have different goals. Accordingly, therapists define the goals of the therapy at different phases. In a general approach, physiotherapy service for amputees can be for training the amputee for ambulation using assistive aid; training the amputee for prosthetic walking; teaching amputee how to care for residual limb; teaching amputee how to care for the sound limb to prevent future ulcers; improving amputee's fitness level to enable him/her to cope with the energy demands of ambulation; facilitating amputee's integration into the environment which is designed for two legged individuals; introducing higher levels of functioning such as sport and recreational activities. (Gailey & Clark 1992; May 2002, 74-108)

It should be noted that in connection with cardiovascular diseases some specific risk factors are highly prevalent among amputees in comparison with general population. High cholesterol, hypertension, diabetes, and inactivity are the risk factors frequently seen. These risk factors put amputees at high risk of cardiovascular diseases (Frugoli, Guion, Joyner & McMillan 2000). The prevalence of the cardiovascular problems indicates the necessity of the exercises aiming at improving and conditioning this system throughout the rehabilitation process.

The therapy method mentioned in this work is in accordance with the guidelines (table A1 in Appendix 5) of the British Association of Chartered Physiotherapists in Amputation Rehabilitation (Broomhead et al. 2003).

7.1 Preoperative phase

During this phase, the therapeutic interventions adapted by physiotherapists mostly revolve around the following goals/ideas: intact limb/upper limb/trunk should be kept mobile and active; in the case of the senior patients respiratory values should be improved so they can cop with the demands of surgery; upper body and trunk musculature should be strengthened in order to prepare patients for using mobility assistive devices; patient should be educated regarding the rehabilitation timeframe, the possibility of phantom sensations, residual limb care, joint contracture prevention, and the possibility of prosthetic limb fitting. (Esquenazi & Meier 1996; Gailey & Clark 1992)

The urgency of the situation makes physiotherapists to decide about the priority of these goals. Presumably, emergency amputations happen in rush, with leaving little time for physiotherapists to plan a treatment. In contrast, non urgent conditions can provide some time for therapists to achieve some of the goals. Patients are often admitted to surgery wards only 1-2 days before the operation (Parvin 2006). Therefore, physiotherapists should get most of the short time by focusing their works on the prior issues. In such a case it sounds logic to give priority to respiratory training (for elderly amputees) and patient education regarding rehabilitation timeframe, phantom sensations, and residual limb care. (Esquenazi & Meier 1996; Gailey & Clark 1992)

If there is plenty of time, as in the case of the long term preventive rehabilitation, some aerobic exercises can be prescribed as both preventive and health improving measures. One study among vascular patients with claudication symptom has documented improvements in the pain free distance of walking and the duration of walking after 24 weeks of exercise program. (Zwierska et al. 2005)

7.2 Acute postoperative phase

Acute postoperative phase is the time between amputation surgery and discharging from hospital. According to the principles of one hospital district in Finland this period usually takes 2-7 days. This phase of rehabilitation is dominated with edema management, pain management, and wound healing. These elements affect the length of the hospitalisation and are taken in consideration in any physiotherapy planning. (Kelly 2007; Sairaanhoitopiirien hoito-ohjelmat 2008)

Recent study by Stineman et al (2008) shows that acute postoperative rehabilitation has been effective in one-year survival, home discharge from hospital (preprosthetic phase is included in the hospitalization period), and prosthetic limb prescription. Goals of physiotherapy at this stage are educating patient concerning residual limb care; preventing muscle contracture; reducing edema; improving physical condition through physical training; teaching the use of assistive aids for ambulation; teaching and assisting patient for easy and safe transfer between furniture or facilities and assistive devices such as wheelchair. (Esquenazi & Meier 1996; Kelly 2007; May 2002, 88-108; Sairaanhoito-piirien hoito-ohjelmat 2007)

Table 1 shows different interventions and techniques adapted by physiotherapists for achieving the goals of this stage. It should be noted that the strong medication used against pain can influence patient’s cognition and muscle function therefore special attention should be paid to patient’s balance while practising any physical activity in standing and sitting postures (Gailey & Clark 1992). At the same time, therapists should be careful to not cause any excessive pressure on the incision and underlying tissues in order to provide a good healing opportunity for the tissues involved (May 2002, 95).

Table 1. Goals of acute postoperative rehabilitation and physiotherapy interventions (Engstrom & Van de Ven 1999, 41-56; Esquenazi & Meier 1996; May 2002, 88-108)

Goal	Intervention or technique
- Residual limb care ◦ Patient Education regarding residual limb care ◦ Preventing muscle contracture ◦ Reducing edema	- By inspecting the skin of the residual limb - By protecting the residual limb from trauma - By regular rubbing and massaging - By proper positioning of the residual limb - By regularly assuming prone posture - By actively and passively moving the residual limb in different directions - By wrapping the residual limb - By not elevating the residual limb
- Physical training	- Active movements (muscle strengthening) ◦ residual limb ◦ sound limb ◦ trunk ◦ upper limbs - Stretching residual limb - Complex movements
- Using assistive aids for ambulation,	- practicing using wheelchair, crutches, walker and so on - using these devices in different environments such as up-hill and down-hill using - practicing suing crutches for walking up stairs and down stairs
- Practising transfers	- transferring from bed to wheelchair and vice versa - transferring from wheelchair to toilet and vice versa

7.2.1 Residual limb care

Residual limb care and educating patient for caring about the quality of her/his residual limb are often emphasised in the literature. The wellness of the residual limb is an important determinant of amputee's participation in rehabilitation, ambulation, and overall prosthetic satisfaction (Meikle, Michael & Susan 2002). Caring about the residual limb should include skin, shape, range of motion, and muscle strength. Amputees should be instructed to frequently inspect the skin of their residual limb for any skin breakdown, redness, rash, haematoma, pressure spots, and tenderness. Furthermore, any trauma to residual limb (especially due to falling) during the healing time can interfere with the healing process. The inflammation and possible infections that trauma induces can postpone healing. In addition to these, when the incision wound is healed, regular rubbing and massaging of the residual limb can facilitate the movement of the body liquids in oedematous tissues and also can psychologically prepare amputees for accepting their new body form. The residual limb inspection should become a daily routine especially for the amputees who are going to be prosthetic limb users. (Engstrom & Van de Ven 1999, 43; May 2002, 89)

Prevention of Muscle contracture is another issue that should be included in any physiotherapy program. This is achieved through active and passive movements of the hip joint of the residual limb and proper handling of the residual limb. One way of applying passive stretching is by proper position of body in bed. During acute postoperative phase physiotherapists should instruct amputees to not place any pillow under residual limb or between thighs while lying in supine. Pillow under residual limb increases the risk of hip flexion contracture and pillow between legs increases the risk of abduction contracture. In this position patient's upper body should not be elevated for a long time in order to avoid accumulation of edema. Patients should be encouraged and assisted in lying on their side often to prevent the formation of bedsores. Prevention of bedsores is especially important among diabetic patients who suffer from neuropathy. Patient is assisted to lie on his/her side; the intact limb is bent and resting on the bed; a pillow is placed between the residual limb and the intact limb; the residual limb rests on the pillow while hip is in straight line with trunk. Lying in prone posture is a good way of applying passive stretching on hip flexors. If there is not any cardiopulmonary condition patient is assisted to lie in prone. In this position both lower limbs are next to each other without hip abduction. (Gailey & Clark 1992; May 2002, 94-98; Sairaanhoitopiirien hoito-ohjelmat 2007)

One important goal of the acute postoperative physiotherapy is reducing edema in the residual limb. Postoperative edema in the residual limb requires attention from therapists and patients. At the acute stage one measure taken against edema is using elastic bandages. Using elastic bandage makes the daily inspection of the wound easier. This bandage should exert a continuous pressure that is greater distally than proximally. (Sairaanhoitopiirien hoito-ohjelmat 2007)

Bed to wheelchair and wheelchair to toilet are the usual immediate cases of transfers that are instructed and assisted by physiotherapists during acute postoperative. Ambulation using assistive aid (wheelchair, crutch, walker, and etc) is taught at this stage when the need for transfer rises. (Gailey & Clark 1992; May 2002, 94-98)

7.2.2 Improving physical condition

Mobility in the bed, transferring between bed and wheelchair, using walking assistive aids, and balancing body in unipedal standing posture require muscle strength in upper body, trunk and muscles of sound limb. If a physiotherapist notices that her/his amputee is weak in performing some of these functions then an exercise program should be planned to improve patient's strength and thereby influence the performance of these functions. The goal is to improve muscle strength through functional movements but if this approach encounters limitations then every muscle group within these areas can be strengthened separately. Usually it is recommended to include strengthening of the hip extensors and abductors and stretching of the hip flexors in any exercise program planned for the residual limb (see subtitles 6.1 & 6.2). While planning exercise program therapists should take in consideration the cardiopulmonary capacities of the amputee specially that diabetic patients and patients with PVD are suffering or are prone to vascular disorders. (Engstrom & Van de Ven 1999, 41-56; Gailey & Clark 1992; May 2002, 95-100)

An exercise program if feasible should include patient's entire body and should be performed within the pain free range. Such a program should specifically include exercises for the prosthetic side. These exercises are for training hip flexion, extension, adduction, and abduction. Another part of the training program is concerned with sound lower limb. Training sound lower limb is very important because at this phase of rehabilitation it is the only mean for standing. Training sound lower limb means performing all the movements of the joints of the limb. For achieving proper training at the hospital ward setting different methods such as manual application of resistance should be practiced. Training trunk muscles is another part of the exercise training. The goal is to eventually increase pelvis control. Training upper limbs is crucial because at this stage most of the patient's ambulation is achieved by using assistive devices that are manoeuvred by hands. Another important group of trainings is performing complex movements. Complex movements are either functional daily activities or are the manoeuvres that help in transferring and positioning body. Dressing is a sample of these movements. Table A2 in Appendix 6 shows a sample of such a training program. (Engstrom & Van de Ven 1999, 41-56; Gailey & Clark 1992; May 2002, 95-100)

7.3 Preprosthetic phase

The goal of this stage is to prepare amputees for prosthetic lime fitting if that is their goal. To achieve this, physiotherapy treatment should include improving residual limb shape; prevention of the soft tissue contractures; and physical training program. In Finland since the sutures are removed (about 10 days post surgery) until the time when the first prosthetic limb is fitted (2 months post amputation) can be considered as preprosthetic stage (Sairaanhoitopiirien hoito-ohjelmat 2007).

At this phase some patients might be fitted with air-filled prosthesis during therapy sessions. This prosthesis enables patients to have a gentle weight bearing on the residual limb and practice bipedal standing. The air-filled prosthesis consists of an external frame and a bag that would holds the stump. This prosthesis can be used for practicing walking and for the functional trainings that are performed in the standing posture. While practicing with air-filled prosthesis residual limb is protected by using a silicon liner. (Respecta 2008)

During this phase, physiotherapeutic rehabilitation aims at shaping the residual limb; improving balance (with and without external support); strengthening upper limbs, trunk, intact limb, and residual limb; stretching and maintaining range of motion of the hip joint; and initiation of prosthetic walk using air-filled prosthesis. (Gailey & Clark 1992; Sairaanhoitopiirien hoito-ohjelmat 2007)

In connection with the environments (home and work place) in which the amputee often dwells, an assessment by a physiotherapist is recommended. Such an assessment helps to find out about the need for possible modifications. For instance, if amputee has to climb into a bath tube for taking shower but with his new condition it has become impossible for him to do it independently then changing the tube to another device can be a possible recommendation. (Broomhead et al. 2003)

7.3.1 Shaping the residual limb

Goal for residual limb care is similar to acute postoperative phase. Patient education regarding residual limb care; preventing muscle contracture; and reducing edema are goals of this phase. Shaping the residual limb is still an important issue to address. Indeed, the longer it takes for the residual limb to get to a stable size and shape the longer it would take to be fitted with a definitive prosthesis. To hasten the formation of a residual limb with stable size and therefore earlier prosthetic gait, different methods are put in practice. (Sairaanhoitopiirien hoito-ohjelmat 2007)

Elastic wrap, shrinkers, and silicon (gel) tube are usual methods for reducing edema and shaping the residual limb. Amputees and their caregivers should be taught how to wrap the residual limb using these methods. While using elastic bandages, one way of wrapping is by using two 6-inch and one 4-inch bandages. Figure A7 in Appendix 4 shows how this is done. Regarding wrapping there are some important points to consider, the limb should be wrapped without any wrinkle to prevent unwanted irritation of the skin; and the bandage should exert a pressure that is greater distally than proximally. (Gailey & Clark 1992; May 2002, 88-94)

Another method for reducing edema and shaping the residual limb is by using silicon tubes. Silicon tubes are like tick silicon socks. These tubes are used a few hours a day (Respecta 2008). According to Haberman (1995) silicon (and later on gel) liners came into use in order to prevent skin irritation or skin breakdown and also to provide more even distribution of pressure on the socket walls.

7.3.2 Preventing soft tissue contracture

Flexion or abduction contracture in hip joint remains an issue of concern at this phase of rehabilitation as well (May 2002, 94; Schuch 1992; Standards of Care 2004). This problem is considered a subsequence of imbalance in muscle strength, tightness in facia, protective reflex, and mal positioning the residual limb (May 2002, 94). Flexion or abduction contractures in the hip joint can cause knee instability during prosthetic ambulation. For this reason, it is critical to teach patients even from the first day post amputation about the adverse effects of contracture in hip joint and how they can avoid it. (Kelly 2007)

Mal positioning of the residual limb is a major reason for soft tissue contractures in residual limb. Mal positioning refers to the prolonged positioning of the residual limb in flexion or abduction. In transfemoral amputees this condition is often due to prolonged sitting position (for instance, in wheelchair), lying with a pillow under residual limb, and keeping the joint in abduction for instance while lying. Therefore, as soon as patients are able to roll over in their bed they should be instructed to lie in prone posture in order to apply some stretching to hip joint; and to follow a stretching program. (Gailey & Clark 1992; May 2002, 94-98)

7.3.3 Physical training program

Physical training programs for transfemoral amputees at this phase of rehabilitation should aim at improving balance; improving or maintaining range of motion of the hip joint; strengthening muscles to make the use of assistive aid (wheelchair, crutch, walker, and etc) and later on walking, if feasible; and improving cardiovascular fitness. (Gailey & Clark 1992; May 2002, 192-207)

In connection with improving balance it is said that functional outcome of rehabilitation process in different levels is strongly related to balance in standing. The results of one study among elderly (>60 years old) amputees show that one year after amputation only 46% of the research population were able to stand balanced on their intact limb (Schoppen et al. 2002). Furthermore, falling with/without injury to residual limb is known to have strong relation with balance. The results of one study shows that 58% of unilateral and 27% of bilateral amputees (research population = 164 person) who had answered the questionnaire of this study had at least one fall during the 12 months period before research (Kulkarni et al. 1996). Another study in which data from 3 different periods have been compared states that 32-35% of amputees have had fall/s during inpatient rehabilitation (Gooday & Hunter 2004). The prevalence of weak balance ability and the big number of falls indicates the need for physical training aiming at improving balance.

At this phase of rehabilitation, the setting is not hospital room any more and therapists might have more options for using functional movements in their training techniques than acute postoperative. The ultimate goal is to empower amputees for achieving a level of strength, flexibility, balance, and functional ability needed for prosthetic limb fitting (Gailey & Clark 1992; May 2002, 192-207).

When an exercise program is planned and while it is put in practice, attention should be paid so the exercises are performed in the pain free range. This prevents the exercises from exerting excessive pressure on the healing tissues. Another recommendation is the use of water exercises. A big number of the transfemoral amputees are elderly patients whose weak balance is even worsened by their amputation. Physiotherapists should introduce water exercises not only to this group of patients but to all of the amputees. Patients with fear of falling can find it safer to perform exercises in water where they would have support from their therapists. If the physical training program includes water exercise, therapists should first make sure that the incision is closed and healed. Table A3 in Appendix 6 demonstrates a sample of such a training program. (Broomhead et al. 2003; Gailey & Clark 1992; Sairaanhoitopiirien hoito-ohjelmat 2007)

7.4 Prosthetic phase and gait training

Prosthetic phase of rehabilitation starts when amputees receive their first prosthetic limb. At this phase the goal is to enable the client to gain the maximum level of functioning according to his/her conditions (Carroll & Edelstein 2006, 15). This phase is highlighted with gait training. Not everybody is appropriate candidate for prosthetic limb ambulation. The results of one study shows that of the participants in a preprosthetic rehabilitation program 38% proceeded successfully to prosthetic level while 58% abandoned the idea of prosthetic ambulation. The main reasons for refusing prosthetic ambulation had been hip flexion deformity, general weakness, amputation in the contra lateral leg, chronic obstructive airway disease, stroke, pain in the residual limb, and problems in the contra lateral leg (Marzoug, Landham, Dance & Bamji 2003).

In Finland at the end of the preprosthetic phase (6 weeks post operation) amputees are evaluated for whether they are candidates for prosthetic limb ambulation or not.

When amputees possess the required conditions they are introduced to prosthetic departments. Usually the first prosthetic limb is fitted 2 months post operation. The decision for prescribing prosthesis is based on the condition of the residual limb, lower limbs, upper limbs, general condition, cognitive capacities, and psychological condition (Sairaanhoitopiirien hoito-ohjelmat 2007). During this process therapists are often consulted on whether an amputee is ready for the definitive prosthetic limb and/or what component would match amputee's general condition better. Therefore, physiotherapists must become familiar with components of prostheses and the concepts related to the function of these components; to perceive amputee's needs accurately; to provide effective treatment; to give reliable consultation; and to prevent possible long term side effects of the amputation.

To receive prosthesis, residual limb should be in proper condition. This means that the wound is healed; skin does not have blisters and rash; edema had shrunken; there is no inflammation; there is no tenderness when squeezing by hand. As for the sound lower limb, appropriate condition means that joints have sufficient range of motion; joints have no pain that limits weight bearing; muscles are strong; there is not limb threatening condition in the sound limb. For many amputees strong and healthy upper limbs are of high advantage because they would have sufficient strength for transferring between wheelchair and bed; and they would have sufficient strength for using assistive devices for walking. In addition to all of these, patients should be in a generally good condition to be eligible for prosthetic fitting. General good condition means that cardio respiratory performance is sufficient for prosthetic ambulation; there is no significant balance problem; and diabetes is under control and the swelling in the limbs has been taken care of. With regard to cognitive and psychological orientation, patient should be oriented in time and place; patient is able to practice according to the instructions; patient is willing to have prosthesis; and patient is motivated to participate in strength training. (Sairaanhoitopiirien hoito-ohjelmat 2007)

Physiotherapeutic rehabilitation during the prosthetic phase aims at enabling amputees to have smooth and energy efficient gait, improving postural control, and preventing possible abnormalities in gait and posture or complications such as low back pain. To achieve these aims amputees are trained for finding the center of gravity and controlling the movement of the center of gravity through forward to backward or side to side movements; bearing body weight on the prosthetic limb; balancing in single leg standing; bringing one foot forward and being ready for the next step; and coping with environmental changes (Friel, Domholdt, & Smith 2005, 155-166; Gailey & Clark 1992; May 2002, 199-200; van Asseldonck, & van der Kooij 2006).

After these skills are satisfactory achieved amputee starts to take the first steps. Different safety measures can be used to make sure that patient would not fall. The common safety measure is parallel bars. Amputees can start their walking within parallel bars and in front of a mirror. Physiotherapist might notice different faults in movements of the pelvis and trunk. These would need to be addressed one by one. For instance, therapist might need to verify the toe-off phase, swing phase, and or trunk rotation. Table A4 in Appendix 6 demonstrates a gait training tutorial. Amputees little by little might ask for advanced skills. Walking on uneven surfaces; walking up and down stairs; and changing direction of the walking are some samples (Gailey & Clark 1992; Gailey 2003; Wolff-Burke & Cole 2003).

As it is showed in table 2, training should consist of the practices in which amputee's body is either in stable bipedal standing or in ambulation. Furthermore, the environment should be either dynamic and changing or closed and with no change. In any of these situations other parts of the body (hands and trunk) can be also either without any action or with performing some actions. (May 2002, 199-200; Nederhand, van Asseldonck, & van der Kooij 2006)

Table 2. This taxonomy is designed based on Gentile's theory of motor learning. This table is developed according to the instructions from May (2002, 199).

<table>
<tr><th></th><th></th><th colspan="2">Task = Standing Stable</th><th colspan="2">Task = Walking</th></tr>
<tr><th></th><th></th><th>Without manipulation</th><th>With manipulation</th><th>Without manipulation</th><th>With manipulation</th></tr>
<tr><td rowspan="2">Closed Environment</td><td>Without Inter-trial</td><td>- Standing stable
- Arms and trunk are stable
- Environment is not changing</td><td>- Standing stable
- Arms and trunk are doing some tasks
- Environment is not changing</td><td>- Walking
- Arms and trunk are stable
- Environment is not changing</td><td>- Walking
- Arms and trunk are doing some tasks
- Environment is not changing</td></tr>
<tr><td>With Inter-trial</td><td>- Similar to the conditions above only the task is a little different for example standing with one foot on a stool</td><td>- Similar to the conditions above only the task is a little different for example standing with one foot on a stool</td><td>- Similar to the conditions above only the task is a little different for example walking uphill</td><td>- Similar to the conditions above only the task is a little different for example walking uphill</td></tr>
<tr><td rowspan="2">Dynamic Environment</td><td>Without Inter-trial</td><td>- Standing stable
- Arms and trunk are stable
- Environment is changing</td><td>- Standing stable
- Arms and trunk are doing some tasks
- Environment is changing</td><td>- Walking
- Arms and trunk are stable
- Environment is changing</td><td>- Walking
- Arms and trunk are doing some tasks
- Environment is changing</td></tr>
<tr><td>With Inter-trial</td><td>- Similar to the conditions above only the task is a little different for example standing with one foot on a stool</td><td>- Similar to the conditions above only the task is a little different for example standing with one foot on a stool</td><td>- Similar to the conditions above only the task is a little different for example walking uphill</td><td>- Similar to the conditions above only the task is a little different for example walking uphill</td></tr>
</table>

For imagining the combinations described above, compare the following situations: i) amputee is standing in the therapy room without any action, ii) amputee is standing in the corridor of the therapy unit where people are passing and carrying tools, iii) amputee is standing in the therapy room while reaching forward with his trunk and arms to place a ball in a basket, iv) amputee is standing in the corridor of the therapy unit where people are passing and carrying tool and at the same time he is bending forward to drink from a water cooler. In all of the situations amputee is keeping a stable bipedal posture while either his environment has changed or the use of his upper body and trunk has changed. To change the task so there would be a modification in the motor plan amputee could place his sound limb on a stool. Naturally, physiotherapy and gait training start from easier combinations and advance to the more demanding ones.

Transfemoral amputees demonstrate asymmetry in gait, with shorter stance phase on the prosthetic side compared to the sound side and the wider stride compared to non amputees but, “not in all cases symmetric gait should be an aim of rehabilitation” (Hof, van Bockel, Schoppen, & Postema 2007). Amputees usually terminate their gait using the intact limb. They adjust their step length so they can arrive at destination with their sound limb. Due to the limitations that this might bring, it is recommended that physiotherapists train amputees for terminating walking using prosthetic limb as well (Vrieling et al. 2008). During walking amputees consume bigger amount of energy compared to non amputees and oxygen consumption increases significantly with the speed of gait (Schmalz, Blumentritt, & Jarasch 2002).

Improving dynamic balance control should be included in any physical training of the amputees at prosthetic phase. Nederhand et al (2006) assessed dynamic balance control in amputees and noticed that their balance is not in accordance with weight distribution between legs. They suggested physical training for improving balance for functional purposes. Therefore physiotherapists should instruct amputees to distribute their weight evenly between both legs when walking and when standing. (Nederhand et al. 2006)

Another condition that physiotherapists should be aware of is the prevalence of low back pain among amputees. According to Ehde (2000) amputees are at high risk of developing low back pain. Therefore, preventing or treating low back pain should be considered while planning physical training programs. In a research for discovering the reason for low back pain among amputees Firel et al (2005) observed that pain was associated with increased length of iliopsoas, decreased strength of the back extensors, and decreased endurance of the back extensors. Therapists should consider these reasons among the possible reasons for the low back pain of their amputee clients. Both as treatment and as preventive measures, physiotherapists can prescribe exercises that increase the strength of the iliopsoas, back extensors and increase the endurance of the back extensors. (Ehde 2000; Firel et al. 2005)

8 GAIT DEVIATIONS

Previously the mechanism of hip, pelvis, knee, and foot/ankle stability were discussed. Any excessive stability and any unwanted instability in these areas can lead to some gait disorder. Furthermore, any disturbance in the mechanical properties of the prosthetic limb including weight, height, socket fitness, socket design, and alignment and any problem with suspension can cause walking disorders as well. Lateral trunk bending, abducted gait, exaggerated lordosis, circumducted gait, vaulting, and medial/lateral whips are some of the frequently seen gait abnormalities among amputees.

Lateral trunk bending is one of the gait deviations. Lateral trunk bending is manifested by amputee’s trunk bending towards the prosthetic side during stance phase. This abnormality is seen when the lateral wall of the socket is not providing enough initial adduction which is needed for activating hip abductors; the medial wall of the socket is higher than it should; prosthesis is short and therefore hip has dropped on the prosthetic side; hip abductors on the prosthetic side are weak; or there is pain and uneasiness on the distal lateral side of femur. (Berger 1992; Choi, Sugar, Fish, Satzer, & Krabak 2003, 38-39; May 2002, 186-192)

Abducted gait is another gait deviation. This abnormality is present when the distance between legs is significantly bigger than 5-10cm. This abnormality exists when prosthesis is long; there is pain and uneasiness in the medial-proximal end of the thigh; hip abductors are contracted; prosthesis has alignment issue that has caused the shank to be in valgus position. (Berger 1992; May 2002, 186-192)

Exaggerated lordosis is a gait deviation that is seen throughout the stance phase when there is contracture in hip flexors; and socket design does not provide sufficient initial hip flexion. The initial hip flexion is provided by aligning the socket such that the hip joint is in 15º of flexion. If the initial flexion is not sufficient, amputee forces his lumber vertebra into hyper lordosis wishing to activate hip extensors in order to provide some stability at knee joint. In addition to these, the gait deviation is seen when hip extensors or abdominal muscles are weak. (Berger 1992; Choi et al. 2003, 38-39; May 2002, 186-192)

Circumducted gait is a gait abnormality that occurs when amputee's leg moves in a curved line while in swing phase. This problem is present when prosthesis is too long and amputee has to move his leg to side to easily clear the ground; there is too much stability in knee component which causes it to maintain an extended alignment during swing phase; amputee has lack of confidence for flexing knee because of muscle weakness; or prosthesis is not suspended efficiently and therefore during the swing phase it drops down. (Berger 1992; Choi et al. 2003, 38-39; May 2002, 186-192)

Vaulting is a gait problem that occurs when amputee rises on the toes of the intact foot during the swing phase of the prosthetic limb. Vaulting is seen when prosthesis is too long; prosthesis is not suspended efficiently; there is inadequate friction (or swing control) in the knee component that can cause excessive knee flexion and therefore excessive heel rise at the beginning of the swing phase (figure A6 in the Appendix 1). This situation in turn elongates the duration of the swing phase and causes the amputee to keep his hip elevated for a longer time. If hip elevators fail, amputee compensates it with rising on the toes of the sound side. (Berger 1992; Choi et al. 2003, 38-39; May 2002, 186-192)

Medial and lateral whips are other gait deviations that are seen at the beginning of the swing phase. Medial whip is when heel moves inward and knee moves outward. Lateral whip is when heel moves outward and knee moves inward. Wrong alignment of the knee component can be a reason for whips. Another reason can be that knee component is incorporated with excessive external rotation in medial whip disorder or excessive internal rotation in lateral whip disorder. Problems with foot component can be the reason for whips too. For example when foot rotates laterally at heel strike a medial whip can happen. This unwanted lateral rotation can occur with too hard heel cushion or too hard plantar bumper. Foot slap can be a cause of whip too. In this case foot plantar flexes rapidly when weight is transferred to foot. This can happen because of the too soft plantar flexion bumper. Another reason for whips can be that heel rises unevenly. (Berger 1992; Choi et al. 2003, 38-39; May 2002, 186-192)

9 DISCUSSION

Amputation, prosthesis and rehabilitation are three major topics discussed in this thesis. At the beginning of the work (chapters 3-5) amputation, complications of the operation, etiology/prevalence, and biomechanical considerations related to amputation at transfemoral level are discussed. These give background information on what happens to different tissues during amputation and how amputation affects the biomechanics of hip and pelvis. Biomechanical changes can be viewed from different perspectives such as muscle function and skeletal deformity. Due to the amputation at this level some of the muscles around thigh would have different properties than before. Smaller mass, shorter lever arm, muscular rather than tendon insertion, and smaller pulling angle can cause some muscles (such as adductor magnus) to have mechanical disadvantage in comparison with their antagonists. This can lead to muscle contractures. It is discussed that for some amputees, muscle contracture at hip joint would have flexion or abduction pattern. Knowing these physiotherapists would be able to plan therapy programs according to biological and biomechanical changes.

With regard to the amputation surgery, this thesis is not concerned with different surgery techniques and how each technique might affect rehabilitation of the amputee. I think, from the view point of physiotherapy practice, the outcome of the amputation surgery (with respect to mechanical properties of different tissues) is more important than the technique of the surgery. This explains the need for knowing where and how the residual muscles are anchored rather than knowing how the surgery has progressed. There is an endless amount of literature related to amputation surgery but I needed a source that would explain, in brief, what happen to different tissues. The only source that I had full access to the text was a book written in 1992 (The book is also printed in 2002.) There were two newer books as well that I had partial access to the text. In Finland there is a lack of the books that are in English and are made for physiotherapists and that they briefly explain the surgery technique of some common conditions.

In this thesis transfemoral prosthetic limb (chapter 6) is described with some details so readers would know what components are there and how these components affect prosthetic limb gait. Prosthetic components and their alignment determine the stability of the knee joint during the stance phase and the ability to flex knee during the swing phase. Prosthetic deign and amputee's physical condition determine the amount of the voluntary control needed and the involuntary stability that should be provided. Some elements related to prosthetic limb that interfere greatly with the smoothness of the prosthetic gait are socket design, suspension, knee component, ankle/foot component and weight bearing. Socket is related to weight bearing and adherence of prosthetic limb to body. Weight bearing issue is closely related to the design of the socket and the fact that weight is born via socket's walls and ischium rather than femur. Suspension method and how well the prosthetic limb has maintained an intimate contact with the residual limb have been discussed as well. All of these parameters determine the smoothness of the prosthetic gait and therefore how energy efficient prosthetic gait is. The great impact of amputation and prosthesis on planning rehabilitation program and on the effectiveness of the therapy sessions demanded the inclusion of these elements in this thesis.

With regard to prosthetic limbs, there are plenty of new articles published in which different components are examined. It was difficult, though, to find a source that is targeting physiotherapists and that it contains adequate information about different prosthetic components. Here again the only source with full access to the text that I could find was from 1992 (The book is also printed in 2002.) In connection to prosthetic components and their effect on smoothness of gait, speed of gait, usage on different surfaces, energy consumption, and quality of life I think there could be plenty of topics for physiotherapists to perform researches.

Finally, in this thesis different phases of rehabilitation and gait deviations are discussed (chapter 7 & 8) to enable physiotherapists to plan therapy programs that are responsive to amputee's needs at each phase. In this part four phases of the rehabilitation plan for amputee clients were explained. Issues of concern, goals of therapy, and physiotherapy interventions were explained for each phase. The importance of the residual limb care and physical condition enhancement were explained. And finally prosthetic gait training was put in details. Physiotherapy for amputees is the area in which the least amount of articles is found. There are plenty of unanswered questions in different areas of rehabilitation. What is the best physiotherapeutic solution for vaulting? What can be done to prevent hyperlordosis among amputees? What is the connection between prosthetic weight bearing and dynamic balance?

During data collection phase, whenever I came across the articles that would match the topic in question I would try to find the original article (full text) in the journals available via Nelli portal. At first the only criterion for selecting the literature was that the articles and the books should be new and match the topic in question well. To have enough articles for writing this thesis I had to expand the time span little by little until the time span reached 1990. Difficulties finding relevant articles made the process of collecting literature very time consuming.

When choosing the articles I was aware of the issue of reliability. Therefore, I paid attention to the method of data collation, the use of measuring tools, implementation, analysing the data, and the argumentation for drawing the conclusions. Finally, the searching process provided me with enough information for writing this tool kit. One issue that challenged me greatly during the process of collecting literature was due to the fact that there is a lack of evidence based practices concerning the physical rehabilitation of amputees. This makes a big area for physiotherapists to perform researches. Another issue that I noticed was that in Finland we lack a systematic team approach to amputation and also there is not any association of physiotherapists who are trained or skilful in rehabilitating amputees.

The most important issue that I have realised is that without having adequate knowledge of the prosthetic designs and the biomechanics of knee and pelvis control it would be difficult to solve some gait problems.

10 CONCLUSION

Even though the number of the people who undergo amputation surgery reaches hundreds of thousands a year, amputees are not the biggest group of clients for physiotherapists. Nevertheless, therapists are greatly challenged with the physical and psychological complications that amputation brings about for amputees. The physical conditions that are accompanied with amputation are so vast that a team approach to the rehabilitation of amputees has been needed. The complication of the amputation made me to fell the need for an information package that could be quickly used by physiotherapists.

The prim goal of this tool kit has been to provide a set of guidelines that physiotherapists can use for planning rehabilitation program for transfemoral amputees. To achieve this gaol I felt a need for first providing theoretical backbone and then building up a physiotherapy program based on that. Furthermore, throughout of this work, different aspects of amputation have been either addressed or named. This would provide not only the initial knowledge for planning therapy program but also a take off field towards further studies. By going through different chapters of this tool kit I can conclude that this work has been theoretically able to reach its aims. Of course, the function ability of this work remains to be practiced by physiotherapists. This work is meant to be a practical tool kit. Therefore for every phase of rehabilitation different areas of concern have been discussed so physiotherapists would have a bigger picture about their client's condition.

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APPENDICES

Appendix 1: Pneumatic/hydraulic knee mechanism

Appendix 2: Prosthetic foot components

Appendix 3: Elongated swing phase

Appendix 4: Wrapping elastic bandage

Appendix 5: Recommendations for physiotherapy management of adult amputees

Appendix 6: Exercise training programs

APPENDIX 1

Pneumatic/hydraulic knee mechanism

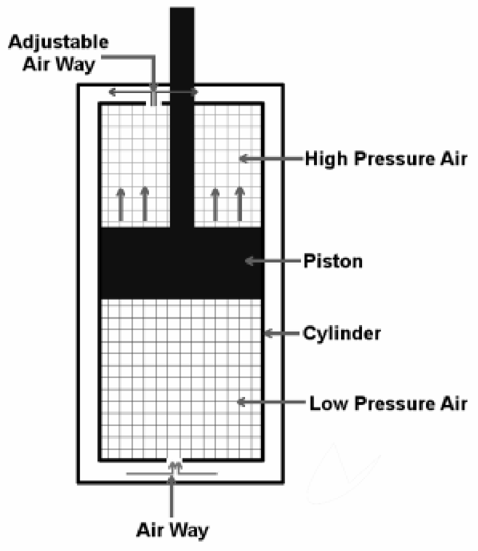


Figure A1. Pneumatic/Hydraulic Knee. This is a schematic figure of an extended pneumatic/hydraulic knee during stance phase. At toe-off when body weight is shifted to the contra lateral leg the compressed air pushes the knee component into flexion. (Author)

APPENDIX 2

Prosthetic foot components

SACH Foot

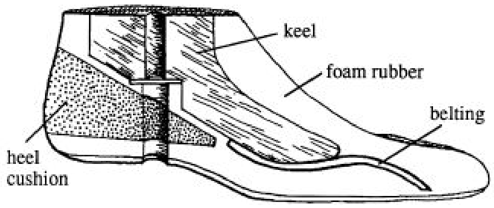


Figure A2. SACH Foot. The part marked as belting is or is not present in all the SACH feet. This metal belt is used for making the keel part longer or shorter and therefore increasing or decreasing resistance to dorsi flexion. (Kapp & Cummings 1992)

Single Axis Foot

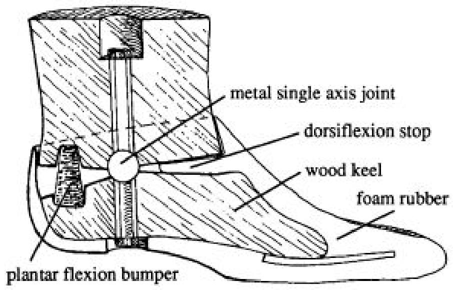


Figure A3. Single Axis Foot. Rubber bumpers provide a limited amount of dorsi and plantar flexion. (Kapp & Cummings 1992)

Soft Keel Foot

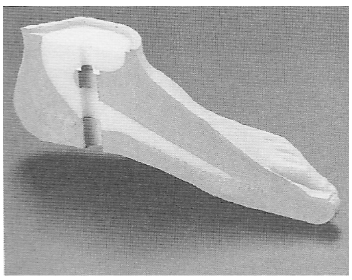


Figure A4. Soft Keel Foot. Seattle foot is a sample of soft keel foot. The white part shows the soft keel. (May 2002, 125)

Multiaxial Foot

Figure A5. Multiaxial Foot. This foot has a 3-point base of support and plantar flexion happen around a separate axis than the one for dorsi flexion. (http://www.college-park.com)

APPENDIX 3

Elongated swing phase

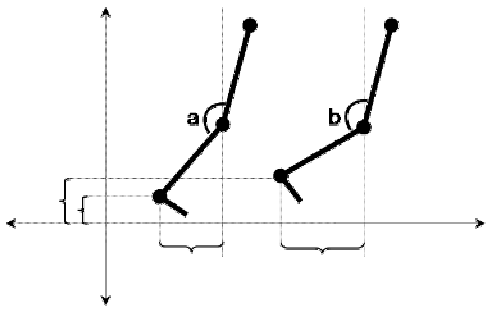


Figure A6. Elongated Swing Phase. The prosthesis on the right has less swing control. At toe-off knee bends more than the prosthesis on the left (bº<aº). This causes a longer distance to be covered during swing phase. (Author)

APPENDIX 4

Wrapping elastic bandage

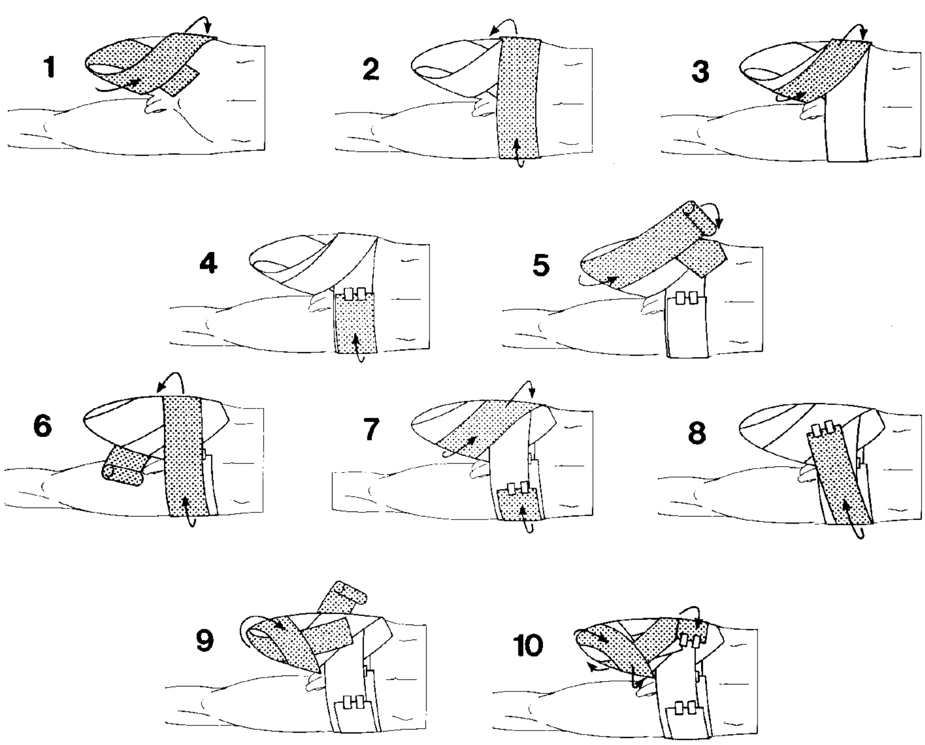


Figure A7. Wrapping Elastic Bandage. This figure shows a method for wrapping residual limb using two 6-inch and one 4-inch bandages. (May 2002, 92)

APPENDIX 5
Recommendations for physiotherapy management of adult amputees

Table A1. Recommendations for physiotherapy management of adult amputees (Broomhead et al 2003).

Therapy Area	Guideline
The Multidisciplinary Team	1. A physiotherapist specialised in amputee rehabilitation should be responsible for the management of physiotherapy care. 2. The physiotherapist should contribute to multidisciplinary team audit, research and education.
Prosthetic Knowledge	3. The physiotherapist should understand the theory of prosthetic componentry and the effects of prosthetic rehabilitation on the remaining body systems. 4. To provide effective gait re-education the physiotherapist should understand the principles of physiological and prosthetic gait and the factors (both physical and biomechanical) that affect them. 5. The effects of prosthetic alignment on pressure distribution within the socket should be understood. 6. The management of residual limb volume changes in relation to socket fit should be understood. 7. The physiotherapist should understand the pressure tolerant and pressure sensitive areas of the residual limb in relation to prosthetic fit. 8. The physiotherapist should understand the different methods of donning and doffing prostheses. 9. The physiotherapist should check the prosthesis for correct and comfortable fit prior to each treatment, until the patient is able to do this for him/ herself. 10. The physiotherapist should examine the residual limb before and after prosthetic use, until the patient is able to do this for him/herself. 11. The patient should examine the residual limb before and after prosthetic use. 12. The physiotherapist should contribute to the decision-making process regarding prosthetic prescription. 13. The prosthetic centre should be contacted if there is malfunction of any componentry. 14. The prosthetic centre should be contacted if the socket requires adjustment in order to achieve a correct and comfortable fit.
Assessment	15. There should be written evidence of a full physical examination and assessment of previous and present function. 16. The patients' social situation, psychological status, goals and expectations should be documented. 17. Relevant pathology including diabetes, impaired cognition and hemiplegia should be noted. 18. The physiotherapist should record the prosthetic componentry, type of socket and method of suspension. 19. A problem list and treatment plan, including agreed goals, should be formulated in partnership with the patient.

The Prosthetic Rehabilitation Programme	20. Prosthetic rehabilitation should aim to establish an energy efficient gait based on normal physiological walking patterns. 21. The physiotherapist should be aware that level of amputation, pre-existing medical conditions and social environment will affect rehabilitation. 22. During rehabilitation the physiotherapist should take into account that prosthetic gait demands higher energy expenditure than physiological gait. 23. The physiotherapist should teach efficient control of the prosthesis through postural control, weight transference, use of proprioception and specific muscle strengthening and stretching exercises to prevent and correct gait deviations. 24. Prosthetic rehabilitation should begin within a maximum of 5 working days after receipt of the prosthesis. 25. During prosthetic rehabilitation patients should receive physiotherapy as often as their needs and circumstances dictate. 26. The prosthesis should be worn for short periods of time initially, increasing in use as exercise and skin tolerance allow. 27. Gait re-education should commence within the parallel bars. 28. Gait re-education should progress through walking within the hospital environment to walking within the home environment. 29. Walking aids should be provided to ensure that prosthetic users, where possible, progress to being fully weight bearing through their prosthesis. 30. Functional skills progressing in complexity should be taught within the patients' limits. 31. Rehabilitation should be functional and integrated with activities of daily living. 32. The physiotherapist should instruct the patient in a range of functional tasks relevant to the goals set with that individual. These may include: a. getting on and off the floor; b. getting in and out of a car; c. going up and down stairs, kerbs, ramps and slopes; d. walking in a crowded environment; e. carrying an object whilst walking; f. walking over uneven ground outdoors; g. changing speed and direction; h. picking up objects from the floor; i. opening and closing a door; j. the use of public transport; k. the use of escalators. 33. Prosthetic users should be encouraged and assisted to resume hobbies, sports, social activities, driving and return to work. 34. The physiotherapist, alongside other professionals, should contribute to the care of wounds during rehabilitation. 35. The physiotherapist, alongside other professionals, should treat scar problems when these occur during rehabilitation. 36. The physiotherapist should contribute to the management of residual limb pain. 37. The physiotherapist should contribute to the management of phantom sensation/pain. 38. When a prosthesis is provided for transfers or cosmetic purposes only, instruction and advice on its safe use should be given.

Patient Education	Use of the Prosthesis 39. Patients/carers should be given information about the prosthesis, its functions and limitations. 40. Patients/carers should be given information regarding the care of their prosthesis. 41. Patients/carers should be given instruction on achieving correct socket fit, considering pressure tolerant and pressure sensitive areas of their residual limb. 42. Fluctuations in residual limb volume and its management should be explained. 43. Guidance should be given on the length of time the prosthesis should be worn and how this should be increased. 44. An explanation should be given on how changing footwear may alter prosthetic alignment and the distribution of pressure within the socket. 45. The patient/carer should receive instruction in the use and care of prosthetic socks. 46. Instruction should be given in the correct use of the type of suspension used. Care of the Residual Limb 47. Techniques for the self-management of phantom pain/sensation should be taught. 48. Advice should given to the patient/carer on the factors influencing wound healing. 49. Instruction should be given to the patient/carer on methods to prevent and treat adhesion of scars. 50. Information should be given on skin care of the residual limb and the potential problems related to poor hygiene, inadequate or overzealous skin care. 51. Patients/carers should be informed that sockets that no longer fit correctly, for whatever reason, can cause skin problems. 52. The patient/carer should be taught to monitor the condition of the remaining 53. Physiotherapists should establish links with their local podiatry/chiropody services ensure that information and education given to patients and carers is consistent. 54. Vascular and diabetic patients, and their carers, should be made aware of the their remaining foot and educated in how they can reduce them. Informed Goal Setting 55. Patients/carers should be made aware that concurrent pathologies and previous mobility affects realistic goal setting and final outcomes of rehabilitation. 56. Patients/carers should be made aware that the level of amputation affects the expected level of function and mobility. 57. Patients/carers should be made aware that they will experience lower levels of function than bipedal subjects. 58. Patients/carers should be informed that the energy cost of prosthetic walking is related to the amputation level. Coping Strategies Following Falls 59. All parties involved with the patient should be made aware that the risk of falling is increased following lower limb amputation. 60. Rehabilitation programmes should include education on preventing falls and coping strategies should a fall occur. 61. Instructions should be given on how to get up from the floor. 62. Advice should be given in the event that the patient is unable to

	rise from the floor. Further Information 63. Patients/carers should be made aware of the possible psychological effects following amputation and how and where to seek advice and support. 64. Patients/carers should be educated in how to prevent secondary disabilities that may occur as a result of prosthetic use. 65. Patient information should be available in a format suitable to that individual. 66. All advice / information given to the patient should be recorded. 67. Information on the following should be made available: a. National & local amputee support & user groups b. Health promotion c. Sporting & leisure activities d. Driving after amputation e. Employment/Training
Discharge and Maintenance	68. A summary of the patient's function and mobility at transfer or discharge from active rehabilitation should be documented in the treatment notes. 69. The prosthetic user should be provided with the necessary contact details to seek help and advice when required. 70. A system should exist for the review of patients after discharge from regular physiotherapy. 71. There should be a process in place for the patient to self-refer to physiotherapy after initial rehabilitation. 72. Additional rehabilitation should be made available if an individual's circumstances change: i.e. medical, environmental, prosthetic, physical, return to work or sport. 73. If prosthetic use is discontinued during the rehabilitation programme the reasons should be documented.

APPENDIX 6

Exercise training programs

Exercise training for acute postoperative phase

Table A2. Exercise training for acute postoperative phase. (Engstrom & Van de Ven 1999, 41-56; Gailey & Clark 1992; May 2002, 95-100)

Exercise group	Technique or sample
- Prosthetic side (residual limb)	- hip flexion, extension, adduction, abduction;
- Sound lower limb	- Leg pressing by pushing therapist's hand; - Flexing hip joint while therapist is holding foot to apply some resistance against the movement; - Abduction and adduction of the hip joint with or without external resistance; - Straight leg raise with and without external resistance; - Resistance training of hamstrings; - Hip extension with and without external resistance; - Dorsi flexion and plantar with and without external resistance;
- Trunk	- Extension and flexion (push-up); - Side bending;
- Upper limbs	- Elbow flexion and extension; - Shoulders flexion, extension, adduction, abduction, and elevation; - Lifting body on elbows (This can be done for example when the patient is sitting in the wheelchair.); - Lifting body on hands (This can be done for example when the patient is sitting in the wheelchair.);
- Complex movements	- Rolling over; - Bridging; - Sitting in bed; - Moving up and down in bed; - Dressing practice (To put on lower garments amputees should use bridging technique while upper garments can be put on in sitting posture.);

Exercise training for preprosthetic phase

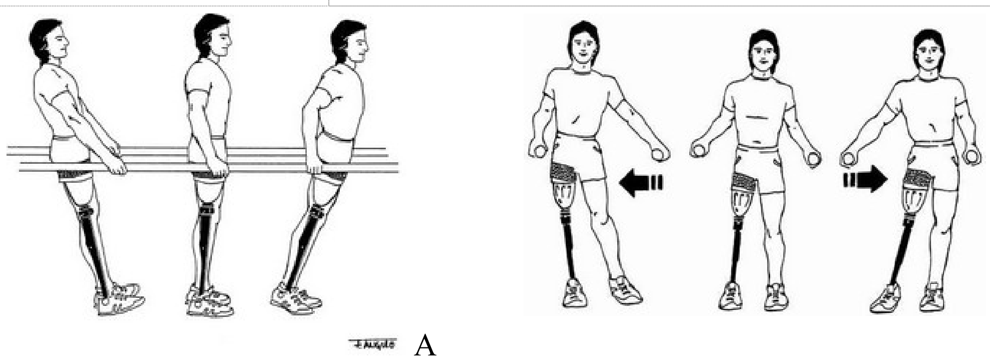
Table A3. Exercise training for preprosthetic phase. (Sairaanhoitopiirien hoito-ohjelmat 2007; Gailey & Clark 1992; Broomhead et al. 2003)

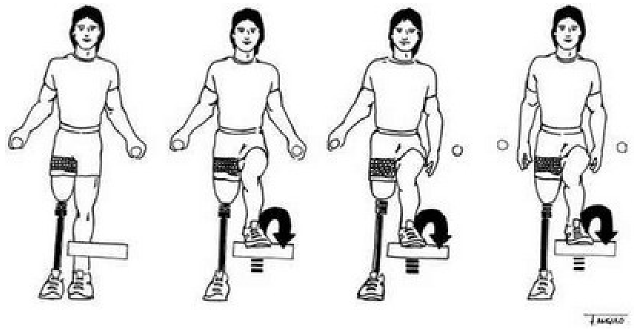
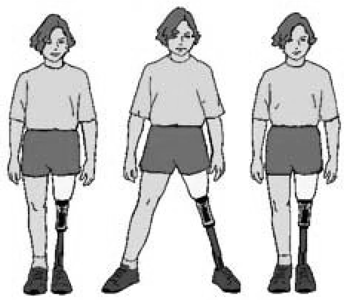
Exercise group	Technique or sample
- Muscle strengthening	- Hip flexion while in supine or standing. - Hip abduction while lying on side or standing. - Hip adduction while in standing or in side bending. Hip is adducted against some resistance. - Hip extensors in prone, supine, and standing. In the case of doing this movement in supine client places some soft billow under his

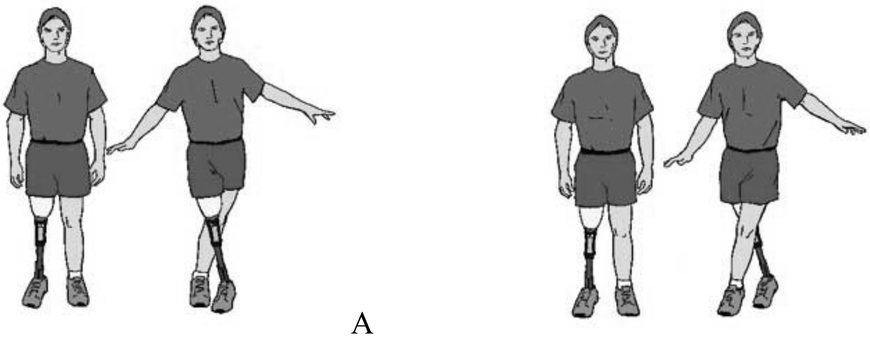
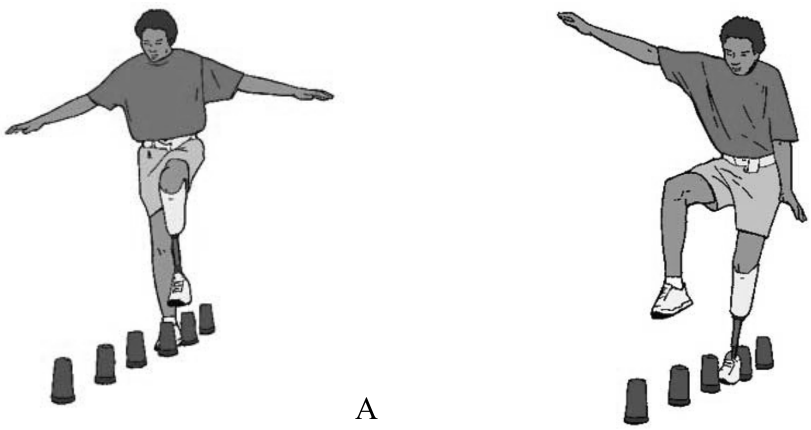
Exercise group	Technique or sample
	residual lime then tries to make a bridge while keeping hip joint in extension. In the case of performing this exercise in standing posture, client stands next to a bed; places the posterior side of his residual limb on the bed; and presses the bed forcefully while extending the hip joint. - Trunk extension training by making one leg bridges or by extending trunk in prone. - Side bending while lying on side and raising the trunk from side. - Trunk flexors while in supine (Sit-ups). - Trunk rotation in both supine and sitting. In sitting this is done while applying some resistance to the movements. - Weight bearing on hands. Client sits on the bed with his legs stretched forward. Client places his hands on the bed next to his pelvis and tries to lift his body from the bed and bear some weight on his hands. This can be done while sitting in a chair or a wheelchair as well. In this case weight bearing can happen both through hands or elbow-forearm. The same movement can be practiced while standing on the sound limb between parallel bars. In such a case client can raise his body while bearing his weight on his hands. - Knee extension while sitting on the side of the bed or while standing. In the standing, client stands on the sound limb between parallel bars; holds the bars and bends his knee to some degree; client extends his knee and raises his body while trying to bear his weight on the sound limb not his hands. - Shoulder extension using weight or training machines of gym. - Shoulder flexion using weight or training machines of gym. - Chest press.
- Stretching	- Stretching all the limited joints that are involved in ambulation with wheelchair and other assistive devices. - Stretching hip extensors and flexors.
- Cardiovascular fitness training	- One leg cranking. - Hand cranking. - Using gym machines for practicing rowing. - Water exercises for legs and arms while using some instruments for applying some resistance. - Swimming.
- Balance training	- Using balance boards while in sitting. A balance board is placed close to the side of an exercise table; client sits on the board with the foot of the sound limb resting on the floor; then he tries to balance his body on the board and keep the balance. Physiotherapy tries to disturb the balance and client resists. - Using a gym ball. Amputee sits on a gym ball while supporting his body using his sound limb. Amputee tries to keep his balance on the ball while physiotherapy is disturbing amputee's balance.
- Functional activities	- Walking with the assistive device that patient prefers. This can be practiced with or without using the air-filled prosthesis. - Reaching forward while standing on the sound limb. - Using wheelchair on even surface, up the hill, and down the hill. - Using stairs for going up and down. - Getting in and out of car. - Getting in and out of the bath tube.

Gait Training tutorial

Table A4. Gait Training Exercises. (Gailey & Clark 1992; Gailey 2003; Wolff-Burke & Cole 2003)

Exercise group	Technique or sample
- Finding the center of gravity	In unsupported single leg stance the only way for maintaining body in standing posture is to move the line of gravity to the base of support which is the foot of the supporting leg. Amputees experience this condition since the time when they practice single leg standing. One aim of the gait training is to help amputees to bring the center of gravity back to the position that it normally has in bipedal standing. Amputees should learn how to move the center of gravity in sagittal and frontal plans. This skill would help to evenly distribute the weight between legs while in bipedal standing and a close to normal pattern while walking (figure A8). (Gailey & Clark 1992)
- Moving center of gravity forward and backward (figure A8 A)	Amputee stands bipedal between parallel bars; grasps both of the bars; tries to divide his weight equally between both feet; without stepping forward and backward and only by moving center of gravity amputee experience weight shift from forefoot to heel.
- Moving center of gravity side to side (figure A8 B)	Amputee stands bipedal between parallel bars; grasps both of the bars; tries to divide his weight equally between both feet; amputee moves center of gravity side to side on the base of support by shifting his weight to one side but without letting the pelvis to drop on the contra lateral side and while the contra lateral leg still bears some weight.
 A B Figure A8. Moving Center of Gravity. Figure A shows forward and backward and figure B shows side to side displacement of the center of gravity. (Gailey & Clark 1992)	
- Single leg weight bearing on prosthetic limb	Full weight bearing for a sufficient length of time is needed for preventing some gait deviations. This can be trained by the exercise showed in figure A9. Amputee stands bipedal between parallel bars. A stool is place in front of the sound foot. The height of the stool changes according to amputee's level of practice. At the start level amputee holds both parallel bars, shift the weight to the prosthetic limb; and places his sound limb on the stool. At the second level amputee holds one of the parallel bars (on the prosthetic side). At the third level amputee places his sound foot on the stool without holding parallel bars. (Gailey & Clark 1992)

Exercise group	Technique or sample
 Figure A9. Single leg weight bearing on prosthetic limb. This exercise starts from easier levels and advances to more demanding levels. (Gailey & Clark 1992)	
- Stepping forward and backward	When amputee can bear his full weight on the prosthetic limb then stepping forward and backward starts. At the beginning stepping is done with bringing sound limb forward and backward while prosthesis bears the weight. Later on the weight bearing limb changes. (Gailey & Clark 1992)
- Partial squats	Amputee stands between parallel bars and while holding the bars perform partial squats. (Wolff-Burke & Cole 2003)
- Wall squat (More advanced)	Amputee lean on a wall by his/her back then perform walk squats. (Wolff-Burke & Cole 2003)
- All fours	Amputee goes on all fours; lifts a limb at a time; and maintain the posture for some counts. (Wolff-Burke & Cole 2003)
- Kick ball	A ball in placed in front of the amputee and he/she tries to kick it using prosthetic limb. (Wolff-Burke & Cole 2003)
- Stepping onto a soft balance board	A balance board is placed in front of the amputee; then amputee steps on it by his/her prosthetic limb; then returns to the bipedal standing posture.
- Stability within socket	The following movements are more complicated and are good for more advanced prosthesis users. Crossing legs has a trunk rotation element that creates a rotational moment in socket.
	Side step (walking). While standing amputee opens his/her legs; places the prosthetic leg to his/her side; bears his/her body weight on both legs; and bring his leg back to starting position. To improve the exercise amputee start the movement by placing his intact lower limb to his side (figure A10). The same way amputee can walk to his/her sides. (Gailey 2003)
	 Figure A10. Side Step (Side Walking). This figure shows how this exercise can be performed on both sides. (Gailey 2003)
	Crossing legs. This movement has a trunk rotation element in it. It helps the amputee to learn how to change the direction of movement. While amputee is standing; he/she puts his/her

<table>
<tr><th>Exercise group</th><th>Technique or sample</th></tr>
<tr><td></td><td>prosthetic leg in front and across the sound leg as seen in figure A11 A. To make the exercise more challenging amputee does the movement by his/her sound limb while the prosthesis is bearing his/her weight (figure A11 B). (Gailey 2003)</td></tr>
<tr><td colspan="2">
A B
Figure A11. Crossing legs. In figure A the sound limb is bearing weight while in figure B the prosthesis bears the weight. (Gailey 2003)</td></tr>
<tr><td></td><td>Cup Walking. This exercise teaches amputee how to control prosthetic limb and place it at the target location. A set of plastic cups are place on floor in a line. Amputee starts the exercise by raising prosthetic limb and placing it between two cups. This is done while the body weight is borne by the sound limb as seen in figure A12 A. The more challenging part of the exercise is when the prosthetic limb bears the weight and sound limb is placed between the next cups as seen in figure A12 B. (Gailey 2003)</td></tr>
<tr><td colspan="2">
A B
Figure A12. Cup Walking. Figure A show the target finding manoeuvre and figure B shows target finding while bearing weight on prosthetic limb. (Gailey 2003)</td></tr>
</table>