Chapter 17

PHYSICAL THERAPY FOR THE POLYTRAUMA CASUALTY WITH LIMB LOSS

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INTRODUCTION

Service members (SMs) that are wounded during active duty often present with multiple injuries. Some of the most devastating wounds can result in the loss of one or more limbs in addition to concomitant injuries. Care of the injured SM is a complex process that requires a team effort that begins at the time of injury continuing throughout all stages of care including postsurgical rehabilitation and frequently persists after discharge. Physical therapists and physical therapy assistants have a central role in ensuring that these SMs with limb loss achieve the maximum possible level of functional ability permitting them to resume their recreational and occupational goals.

SMs who sustain traumatic amputations are generally young and otherwise healthy. They were very active up to the moment of injury, and then suddenly their lives were dramatically changed. As devastating as their wounds may be, they do not want to stop living active and productive lives that include work, sports, and recreational activities. Because of the SMs' pursuit of highly physical activities they are often referred to as "tactical athletes." Therefore, the main focus of rehabilitation in this patient population is application of the orthopaedic sports medicine model to return wounded SMs to optimal levels of physical function. This chapter will present the US military's four-phase program of functional progressive rehabilitation for SMs with lower limb loss.

Rehabilitation should begin as soon after the amputation(s) as possible. Following a comprehensive physical evaluation the physical therapists and physical therapy assistants progress those amputees through the four-phase rehabilitation program:

(1) initial management,
(2) preprosthetic,
(3) prosthetic/ambulation, and
(4) progressive activities/return to active duty.

Individual progression through these phases is a fluid process and will depend on tissue healing, surgical procedures, complications, and individual functional readiness. Patients who undergo further surgery, for example, will return to the earlier phases of rehabilitation. (For an in-depth outline of the Military Amputee Rehabilitation Protocol see attachment at the end of this chapter.) Functional outcome measures are administered at regular intervals to determine and document rehabilitation progress toward short- and long-term goals.

The physical therapist's role in prosthetic training is 3-fold. First, the amputee must be physically prepared for prosthetic gait training and educated about residual limb care before being fitted with the prosthesis. Second, the amputee must learn how to use and care for the prosthesis. Prosthetic gait training can be the most frustrating, yet rewarding phase of rehabilitation for all involved. The amputee must be reeducated in the biomechanics of gait while learning how to use a prosthesis. Once success is achieved, the amputee may look forward to resuming a productive life. Third, the therapist should introduce the amputee to higher levels of activities beyond learning to walk. The amputee may not be ready to participate in sport and recreational activities immediately; however, this is an anticipated goal within the military program. The current rehabilitation program includes higher level training as a standard and most, if not all amputees, are expected to participate as their injuries permit. For those amputees that may receive early discharge, contact information for support and disabled recreational organizations should be provided so they can participate when ready.

Physical Therapy Evaluation

The initial physical therapy evaluation is typically performed at bedside to assess mobility, strength, range of motion, and pain. Amputees with polytrauma will present with secondary injuries other than limb loss that will be evaluated and considered as the rehabilitation plan is prepared.

Physical and occupational therapists can work together with acute patients to eliminate redundancy in the evaluation and cotreatment of mobility and activities of daily living (ADLs). Many ADLs can be evaluated and practiced during occupational therapy and physical therapy evaluations. For example, physical therapists can assess mobility, range of motion, and balance as occupational therapists evaluate and teach dressing activities. Adaptive clothing with tear-away access is helpful to have during an occupational therapist's assessment and to protect patients' modesty as they venture from their room. Every opportunity should be taken to encourage early supervised transfer training with a wheelchair provided when appropriate to allow mobility off the ward and enhance independence. Transfers and wheelchair training activities are examples of early mobility training. The initial evaluation can also be an opportunity to educate the patient and family members about the goals and course of rehabilitation and to develop initial rapport. SMs wounded in the global war on terror will consider their future plans but should be assured that every

feasible opportunity will be made available to them if their goal is to remain on active duty. The wounded SM's goals, which largely determine the long-term rehabilitation plan of care, are important to update as he or she progresses through rehabilitation.

Bedside Management

Generally, the goals of postoperative treatment for the new amputee are to reduce edema, promote healing, prevent loss of motion, increase cardiovascular endurance, and improve strength. Functional skills must also be introduced as early as possible to promote independence in bed mobility, transfers, and ambulation. Further independence and prevention of complications may be addressed with education in the self-care of the residual limb and intact limbs. Moreover, each rehabilitation team member should be aware of the need to assist the patient with the psychological adjustment to limb loss.

PHASE I. INITIAL MANAGEMENT PHASE

The protective healing phase is the first phase of amputee rehabilitation that corresponds with the acute inpatient stay and on average ranges from 1 to 2 weeks depending on the severity and complexity of injury. Patient management strategies for the interdisciplinary team during the first phase include surgical management often with repeated irrigation and debridement of concomitant residual limb(s), wounds, or management of other comorbid conditions. Rehabilitation providers concurrently work together to promote early functional skills, provide patient and family member education, and initiate early conditioning activities as tolerated by the patient.

Functional Activities

Bed Mobility

The importance of good bed mobility extends beyond simple positional adjustments for comfort or to get in and out of bed. The patient must acquire bed mobility skills to maintain correct bed positioning to prevent contractures or excessive friction of the sheets against the suture line(s), scar tissue, or frail skin secondary to burns and other surface wounds. If the patient is unable to perform the skills necessary to maintain proper positioning, then assistance must be provided. Promoting independence as soon as possible is always encouraged because adequate bed mobility is a basic skill required for bed to wheelchair transfers. Independent transfer to a wheelchair is the first step in providing a sense of freedom from the hospital bed and allows the patient to begin moving freely throughout the rehabilitation ward and interact with fellow amputees.

Transfers

Transfer ability is essential during early assessment especially when the rehabilitation team is determining discharge planning from the acute care setting. Independence or limited assistance with transfers makes it possible for the amputee to gain independence quickly and develop a sense of belonging with peers during rehabilitation.

Once bed mobility is mastered, the patient must learn to transfer from the bed to a chair or a wheelchair and then progress to more advanced transfer skills such as toilet, tub, and car transfers. In cases where an immediate postoperative or temporary prosthesis is utilized, weight bearing through the prosthesis can assist the patient in the transfer and provide additional safety. For transtibial amputees who are not ambulatory candidates, a light-weight transfer prosthesis may facilitate more independent transfers. This prosthesis is typically fit when the residual limb is healed and the patient is ready for training. Bilateral amputees that are not fitted with an initial prosthesis transfer in a "head on" manner where the patient slides forward from the wheelchair onto the desired surface by lifting the body and pushing forward with both hands.

Wheelchair Management

The primary means of mobility during early rehabilitation for the majority of amputees will be the wheelchair. Therefore, wheelchair skills should be taught as a part of the early rehabilitation program. Bilateral amputees with complex injuries may require greater use of the wheelchair, while unilateral amputees will be more likely to choose other assistive devices when not ambulating with their prosthesis. Because of the loss of body weight anteriorly when sitting, the bilateral amputee will be prone to tipping backward during propulsion with a standard wheelchair. Amputee adapters set the axle approximately 5 centimeters back, thus moving the center of mass posteriorly to prevent tipping, especially when ascending ramps or curbs. However, this strategy may limit mobility of active wheelchair users by making propulsion less efficient. An alternative method to prevent tipping would be the addition of anti-tippers (simple devices attached to the back of the wheelchair that prevent it from accidentally tipping over backward)

in place of or in addition to the amputee wheel adapters. Transtibial amputees will also require an elevating leg rest or residual limb board designed to maintain the knee in extension, thus preventing prolonged knee flexion and reducing the dependent position of the limb to control edema. Finally, it is recommended that the wheelchair be fitted with removable armrests to enable ease of transfer to or from either side of the chair.

Flexibility

Range of Motion

Prevention of decreased range of motion (ROM) and contractures is a major concern. The best way to prevent loss of ROM is to remain active and ensure full available ROM of affected joints. Unfortunately, not all amputees have this option, and therefore proper limb positioning as previously described must be maintained, especially during the 6 months after amputation. A functional assessment of gross upper limb and sound lower limb motions should be made. A measurement of the residual limb's ROM should be recorded for future reference.

Contracture Prevention/Positioning

Contractures are a complication that can greatly hinder the amputee's ability to ambulate efficiently with a prosthesis; thus extra care should be made to avoid this situation. The most common contractured position for the transfemoral amputee is hip flexion, external rotation, and abduction, and knee flexion is the most frequently seen contracture in the transtibial amputee. During ROM assessment the therapist should determine whether the patient has a fixed contracture or just muscle tightness from immobility that can be corrected with stretching in the near term.

To reduce the risk of contractures, the transfemoral amputee, when in a supine position, should place a pillow laterally along the residual limb to maintain neutral rotation with no abduction. If the prone position is tolerable during the day or evening, then a pillow is placed under the residual limb to maintain hip extension. Transtibial amputees should avoid knee flexion for prolonged periods when sitting or reclining. A stump board will help maintain knee extension when using a wheelchair.

Strengthening

Strength of the major muscle groups should be assessed by manual muscle testing of all limbs including the residual limb and the trunk core stabilizers. Adequate muscle strength will help the patient's functional skill level when performing activities such as transfers, wheelchair management, and ambulation with and without the prosthesis.

Therapeutic Exercise (Bedside and/or Mat)

Lower limb strengthening is imperative to prepare the legs for prosthetic gait training and mitigate the effects of potentially prolonged periods of nonweight bearing secondary to healing of the residual limb(s). Therapeutic exercise progresses from early isometric and active exercise to progressive resistive strengthening and closed kinetic chain (CKC) exercises. During Phase I, specific surgical techniques and healing requirements may dictate the selection of strengthening methods. For example, isometric strengthening may be selected for longer durations where a myodesis was performed and adherence to the bone is required. If there are fewer surgical restrictions, patients may be progressed from isometric strengthening to open kinetic chain and CKC exercises as strength increases permit. Table 17-1 contains a list of early postoperative rehabilitation guidelines. All times annotated are from date of final closure (skin closure with sutures).

Core Stabilization

As soon as bed or mat exercises can be tolerated, the patient with amputation(s) learns the basics of core (lumbopelvic) stabilization, which focuses on intervertebral control, lumbopelvic orientation, and whole body equilibrium, via strengthening of the transversus abdominis and multifidus muscles.[1]

Strengthening this core musculature may minimize or prevent the negative effects following lower limb amputation (eg, low back pain, gait dysfunction, and functional impairments).[2–9] Theoretically, core strengthening can enhance transfer activities, balance, and ambulation because it has been used in athletic and therapeutic settings to enhance neuromuscular pathways, strength, proprioception, and balance and aids in coordination of synergistic and stabilizer muscles.[10–12] Additionally, it has been shown to improve athletic performance and prevent low back pain.[13–15] The transversus abdominis, which is the deepest abdominal muscle, is believed to be a key stabilizer of the lumbopelvic region. It is a thin muscle running horizontally around the abdomen, attaching to the transverse processes of the lumbar vertebrae via the thoracolumbar fascia.[16] The muscle orientation is hoop-like and, when contracted, creates a rigid cylinder resulting in enhanced stiffness of the lumbar spine that creates lateral tension

TABLE 17-1

EARLY POSTOPERATIVE REHABILITATION GUIDELINES

Level(s)	Postoperative Dressing	Weight-bearing Guidelines	Surgical Considerations	Therapeutic Exercise Guidelines
Partial Foot	Fit with shrinker as soon as possible upon removal of sutures or when cleared by orthopaedic surgeon.	Heel pad weight bearing allowed when cleared by orthopaedic surgeon.	N/A	CKC rehabilitation to tolerance.
Symes	Patients casted for 2 to 3 weeks to permit stabilization of heel pad.	NWB for additional 3 weeks after the cast is removed for a total of 5 weeks NWB.	Heel pad and Achilles tendon sutured to tibia.	CKC exercises are appropriate once casted (however, no distal end bearing in cast). Expect delayed prosthetic fitting.
Transtibial	Dressing, figure 8 wrapping. Shrinker sock when sutures are removed.	NWB at distal limb near suture line until sutures removed and cleared by orthopaedic surgeon.	If myodesis is tenuous, the patient may be casted in knee flexion.	Mat CKC exercise may begin immediately if stabilization point on bolster is proximal to the myodesis. Hamstring stretching is restricted for 2 weeks in patients with tenuous myodesis. No other exercise restrictions.
Knee Disarticulation	Postoperative dressing per protocol.	NWB at distal limb near suture line until sutures removed and cleared by orthopaedic surgeon.	Patellar tendon is sutured into the ACL during surgery.	Straight leg raise is restricted to no weights for 2 weeks after surgery. No restrictions thereafter. No restrictions to abduction or adduction movement.
Transfemoral	Hip spica configuration for wrapping with progression to shrinker socks when cleared by the orthopaedic surgeon.	NWB at distal limb near suture line until sutures removed and cleared by the orthopaedic surgeon.	Myodesis of adductor magnus tendon is secured to the lateral femur during surgery.	No active adduction strengthening exercises for 4 weeks. No active abduction strengthening past neutral for 2 weeks (abduction to neutral from adducted posture with supervision). No hip flexion for 2 weeks s/p myodesis to protect distal insertion. Bridging in supine is permitted when performed with bolster under the distal residual limb.
Hip Disarticulation	Hip spica configuration for wrapping. Shrinkers may be ordered to capture hip and provide compression.	Patient may weight bear as tolerated at suture site (ie, sitting) unless restricted for other comorbidity (eg, pelvic or acetabular fractures).	No muscle attachments stressed with end bearing/ sitting on the hip disarticulation.	No exercise restrictions once wound healing complete for end bearing.

ACL: anterior cruciate ligament
CKC: closed kinetic chain
NWB: nonweight bearing
s/p: status post

through the transverse processes.[16,17] Bilateral contraction of the transversus abdominis can contribute to lumbopelvic control by tensioning the fascial structures of the lumbar region via intra-abdominal pressure.[18–20] This helps limit translational and rotational movements in the lumbar spine for which transfemoral and hip disarticulation amputees are extremely vulnerable. The other key deep core stabilizer is the multifidus, which is the largest and most medial of the lumbar muscles.[21] This muscle co-contracts with the transversus abdominis via the thoracolumbar fascia and its functions are to reduce anterior shear force, stabilize the trunk, and act as a primary trunk extensor.[22]

The goals of core stabilization are to control, prevent, or eliminate low back pain; increase patient education and kinesthetic awareness; increase strength, flexibility, coordination, balance, and endurance; and develop strong trunk musculature to enhance upper and lower limb functional activities.

Co-contraction of these deep muscles for core stabilization is a difficult task to learn. Education and training are essential to achieving core stability. Illustrations of the specific muscles and explanations of the exercises are provided to the amputees before practice. Once visualization is established patients are taught how to maintain a neutral spine (the position of most comfort) and how to correctly "draw in" or correctly contract the muscles of the lower abdominal region. Usually this is first attempted in the "hooklying" position, but may need to be taught in the quadruped position using gravity for stretch reflex assistance. It is also important to explain that these muscles are predominantly type 1 muscle fibers providing the longer endurance-type contractions that are important for proper posture. Following instruction and practice, rehabilitative ul-

Figure 17-1. Elizabeth Painter uses ultrasound to identify the transverse abdominis muscle of Gregory Gadson and provide visual feedback for muscle reeducation.

trasound imaging may be utilized to provide further biofeedback and record direct outcome measures of the resting and contracted size of the transversus abdominis as illustrated in Figure 17-1.

Once the basics of neutral spine and proper muscle contraction are learned, amputees will perform a basic core stabilization exercise program. Throughout the training program patients must be reminded to maintain neutral spine, "draw in," or contract the lower abdomen, and gradually increase time spent performing the exercise. Examples of early/level-1 exercises include the following:

- Hooklying: raising hands over head, alternating hands to knees(s), bridging with one leg, crunches, and leg circles;
- Prone: one arm, one leg, alternate arm, and leg lifts;
- Quadruped (if able): one arm, one leg, or alternate arm and leg lifts; and
- Sitting: arms overhead, one leg out, alternate hands to knee.

Advancement occurs by progressing from stable to unstable surfaces (ball, disc), large simple to smaller more complex movements, one plane of movement to multiple/combined planes, short lever arm to longer lever arm, no weights to weights, and slow to fast speed. It is important to maintain the neutral spine during the exercise. Figure 17-2 shows examples of advancing a bilateral transfemoral amputee through a prone back extension progression on a variety of surfaces.

Figure 17-2. (**a–d**) Elizabeth Painter and Barbara Springer assist Gregory Gadson, a bilateral transfemoral amputee, with exercises to advance through a prone back extension progression on a variety of surfaces.

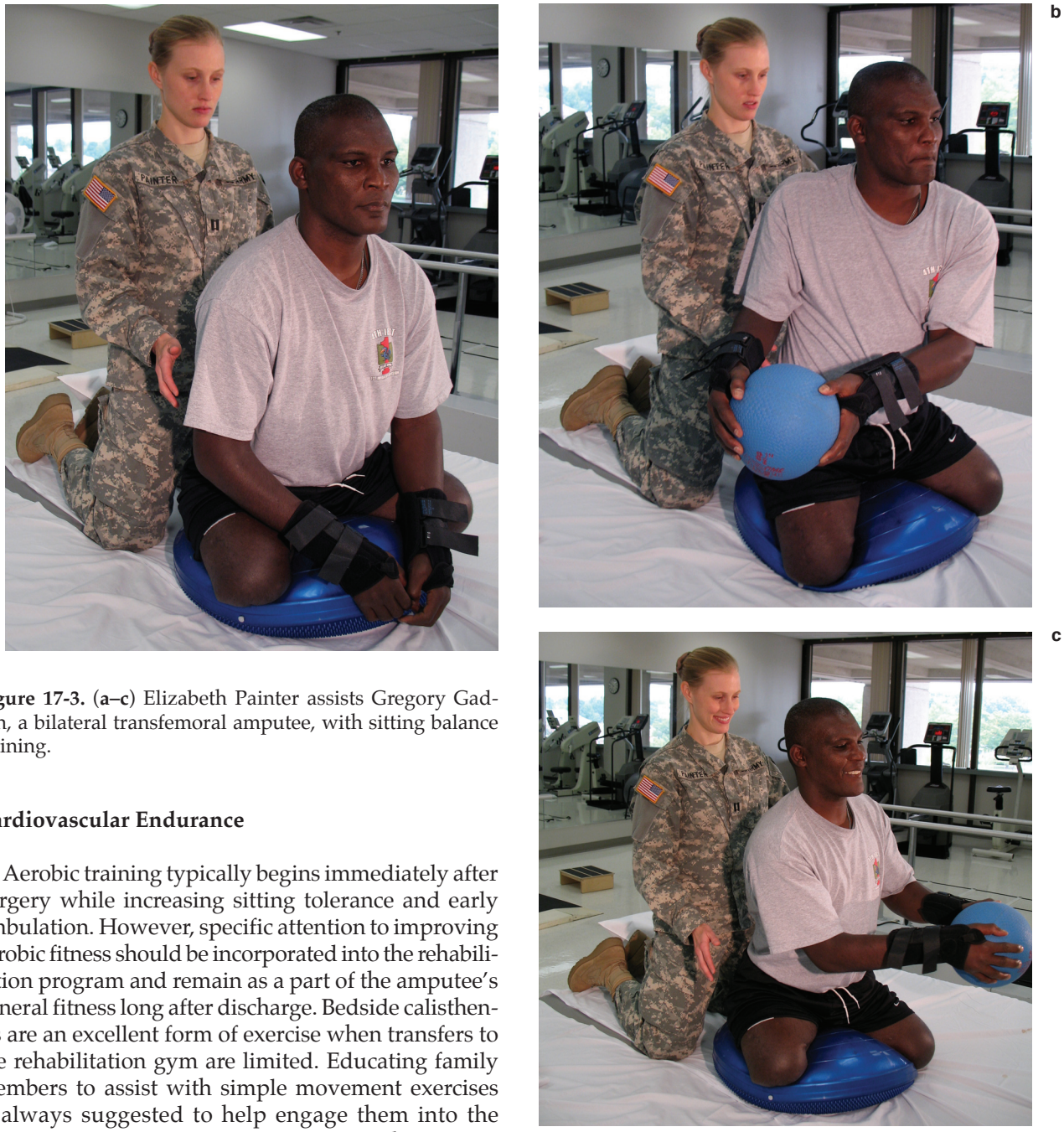

Figure 17-3. (**a–c**) Elizabeth Painter assists Gregory Gadson, a bilateral transfemoral amputee, with sitting balance training.

Cardiovascular Endurance

Aerobic training typically begins immediately after surgery while increasing sitting tolerance and early ambulation. However, specific attention to improving aerobic fitness should be incorporated into the rehabilitation program and remain as a part of the amputee's general fitness long after discharge. Bedside calisthenics are an excellent form of exercise when transfers to the rehabilitation gym are limited. Educating family members to assist with simple movement exercises is always suggested to help engage them into the amputee's early recovery and introduce the need to reduce the number of sedentary hours each day. The three most beneficial exercises are the (1) upper body ergometer (UBE), (2) lower body ergometer, and (3) the treadmill.

Initially, the UBE can be introduced and safely performed with most people.[23–25] The UBE, which has been shown to quickly elevate the heart rate and is also good early conditioning for hand crank cycling, has become popular in the young, active, athletic, and competitive traumatic amputee population.[26,27] Once balance and strength return, lower body ergometry may be performed at first with only the sound limb progressing to use of the prosthetic limb when appropriate. Over time and when the level of fitness improves other equipment may be used such as treadmills, stair climbing machines, and rowing machines. Amputees can enjoy the same activities as the nonamputee population. As a result, swimming and walking are still the ideal exercises for general fitness regardless of age or athletic ability.[28]

Figure 17-4. Andrew Forney, a transfemoral amputee, prepares the shrinker sock over the donning tube.

Figure 17-5. Andrew Forney dons a shrinker sock with a donning tube.

a

b

c

Figure 17-6. Elizabeth Painter assists Gregory Gadson, a bilateral transfemoral amputee, as he stretches the hip while maintaining a neutral spine for increasing or maintaining range of motion for the (**a**) hip flexors prone, (**b**) hip flexors side lying, and (**c**) hip extensors.

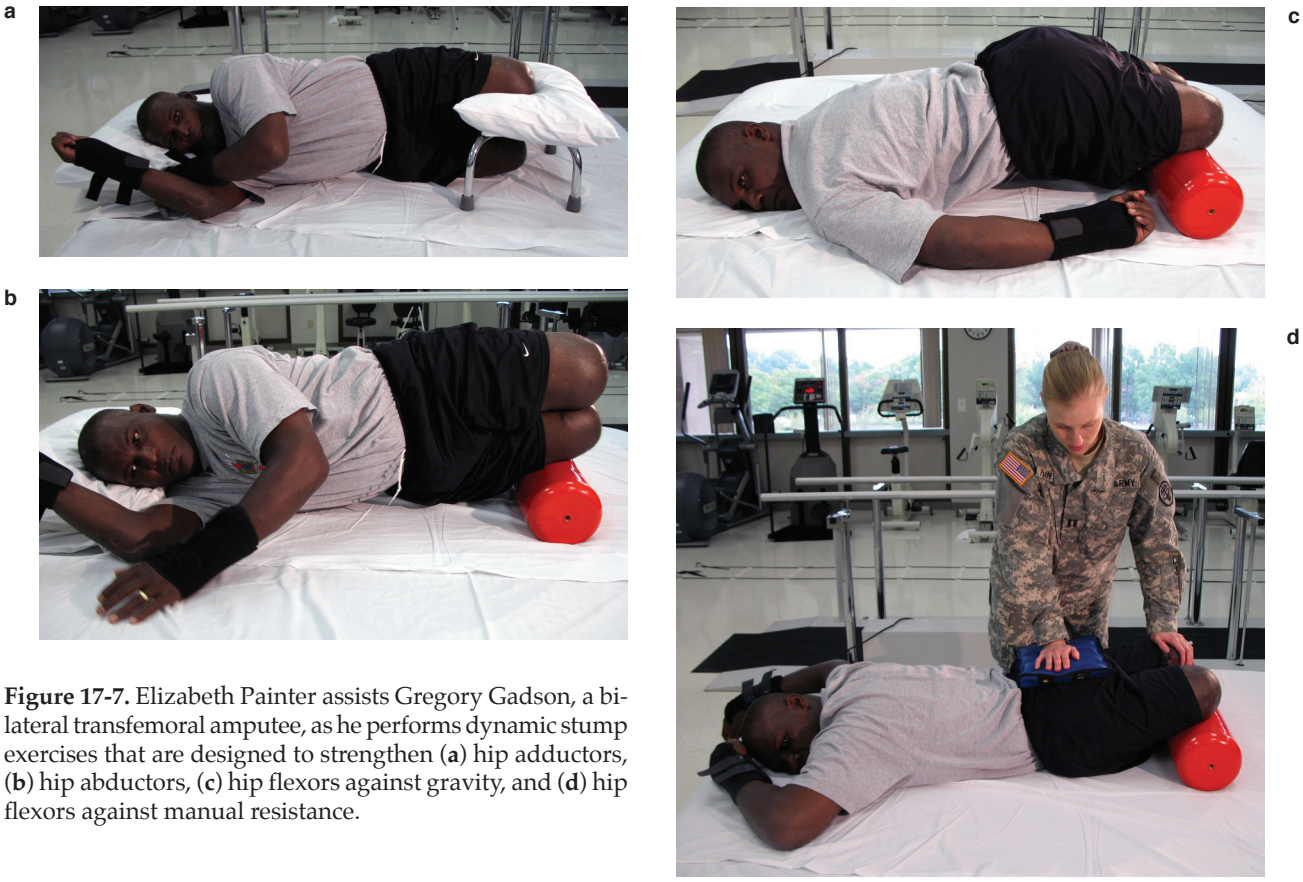

Figure 17-7. Elizabeth Painter assists Gregory Gadson, a bilateral transfemoral amputee, as he performs dynamic stump exercises that are designed to strengthen (**a**) hip adductors, (**b**) hip abductors, (**c**) hip flexors against gravity, and (**d**) hip flexors against manual resistance.

Balance

After the loss of a limb, the decrease in body weight will alter the body's center of mass (COM). Sitting balance is practiced first and then progressed to single limb balance. To maintain the single limb balance necessary during stance without a prosthesis, ambulating with an assistive device, or single limb hopping, the amputee must shift the COM over the base of support (BOS), which in this case is the foot of the sound limb. As amputees become more secure in their single limb support, there is greater difficulty in reorienting the amputee to maintaining the COM over both the sound and prosthetic limbs.[29] Ultimately, amputees must learn to maintain the COM and their entire body weight over the prosthesis. Once comfortable with weight bearing equally on both limbs, the amputee can begin to develop confidence with independent standing and eventually with ambulation.

Sitting Balance

Sitting balance is instrumental for providing the stability required for standing and ambulation. Often the time spent in bed and sitting in a chair can contribute to the deconditioning of the trunk and pelvic musculature. The early rehabilitation period is an excellent time to introduce core stability strengthening exercises and to educate the amputee on the importance of maintaining the strength of the trunk and pelvic musculature often referred to as the core stabilizers. Many of these exercises can be performed in the supine, prone, and sitting positions and when properly prescribed can prove to be extremely challenging and beneficial for even the strongest of amputees. A well-constructed exercise program can provide a foundation of strength and stability that will ease the transition from sitting to standing and walking and create a positive rehabilitation experience. An example of sitting balance training for a bilateral transfemoral amputee is shown in Figure 17-3.

Single Leg Balance

In preparation for ambulation without a prosthesis all amputees must learn to compensate for the loss of weight of the amputated limb by balancing the COM over the sound limb. Although this habit must be broken when learning prosthetic ambulation, single limb balance must be learned initially to provide confidence

Figure 17-8. Matthew Scherer performs a semisupine resisted pelvic rotation drill on Joshua Bleill.

during stand pivot transfers, ambulation with assistive devices, and eventually hopping, depending on the amputee's skill level.[30]

Ambulation with Assistive Devices

All single limb amputees will need an assistive device when they choose not to wear a prosthesis or on occasions when they are unable to wear a prosthesis due to edema, skin irritation, or a poor prosthetic fit. Bilateral transfemoral amputees usually require some form of an assistive device while ambulating with their prostheses.

Ambulate in Parallel Bars

Safety is the primary factor when selecting the appropriate assistive device; however, mobility is a secondary consideration that cannot be overlooked. As a result, initial ambulation training without prosthesis should begin early within the parallel bars. This provides the security of sturdy support while learning the prescribed gait pattern and simultaneously allows the therapist to evaluate the amputee's ambulation potential.

Ambulate with Assistive Devices

The criteria for selection in the early phases and throughout rehabilitation should include the following:

- the ability for unsupported standing balance,
- the degree of upper limb strength,
- coordination and skill with the assistive device, and
- cognition.[31]

A walker is chosen when an amputee has fair to poor balance, strength, and coordination. If balance and strength are good to normal, Lofstrand (Canadian) or regular crutches may be used for ambulation with or without a prosthesis. A cane may be selected to ensure safety when balance is questionable while ambulating with a prosthesis.

A traditional evaluation of the amputee's potential for ambulation includes the following:

- strength of the sound lower limb and both upper limbs,
- single limb balance,
- coordination, and
- mental status.

The selection of an assistive device should meet with the amputee's level of skill, considering that with time the assistive device may change. For example, initially an individual may require a walker during early healing, especially if balance is altered from traumatic brain injury (TBI), but with proper training Lofstrand crutches may prove more beneficial within a short period of rehabilitation and as a long-term assistive device.

Teaching the amputee to negotiate uneven terrain, ramps, curbs, and stairs with assistive devices early in the rehabilitation process is essential. As mobility increases, the freedom and opportunity to independently travel throughout the rehabilitation center and into the community also increases. Often the amputee

Figure 17-9. Joshua Bleill, a bilateral transfemoral amputee, performs unsupported push-ups.

Figure 17-10. Joshua Bleill, a bilateral transfemoral amputee, performs upper limb ergometry on a (**a**) compliant surface and a (**b**) noncompliant surface assisted by Matthew Scherer.

embraces this ability to demonstrate the beginning levels of independence and the ability to spend time with family members and friends away from the hospital environment during weekly community outings.

Patient and Family Education

Compression Dressing

Management of edema and postoperative swelling is critical to an amputee's rehabilitation progression. There are numerous methods for controlling edema and avoiding skin compromise of the residual limb. Early rigid dressings, semirigid dressings, compression wrapping, or the use of shrinker garments for the residual limb can have several positive effects. They can (*a*) decrease edema, (*b*) increase circulation, (*c*) assist in shaping, (*d*) provide skin protection, (*e*) reduce redundant tissue problems, (*f*) reduce phantom limb pain/sensation, and (*g*) desensitize the residual limb. Rigid dressings with transtibial amputees casted in extension will prevent knee flexion contractures and aid in greater confidence with early bed mobility.[32] In the case of transfemoral residual limbs, there may be some value in counteracting contracture forces with specific compression wrapping techniques.

Controversy does exist around the use of traditional compression wrapping versus the use of stump shrinker socks. Currently, many institutions prefer commercial shrinkers for their ease of donning. Advocates of compression wrapping state that they provide more control over pressure gradients and tissue shaping.[33] The use of a shrinker sock within 10 days after amputation has been found to be an equally and potentially more effective means to reduce time from amputation to prosthetic casting from those amputees using wrapping methods.[34] Likewise, even shorter time to prosthetic casting has been observed with transtibial amputees receiving semirigid and rigid dressings.[33,34] Compression therapy can begin with wraps or rigid dressings and progress to shrinkers after the suture line has healed.

Because this is a controversial area, each rehabilitation team should determine the best course for their respective clients and utilize a consistent method among team members. All compression techniques must be performed correctly and in a consistent manner to prevent (*a*) circulation constriction, (*b*) poor residual limb shaping, and (*c*) edema. Likewise, compliance is considered to be an intricate part of the compression

Figure 17-11. (**a–c**) Elizabeth Painter assists Luke Shirley, a unilateral transfemoral amputee, with descending stairs step-over-step.

program. All methods of wrapping or shrinker sock use should be routinely checked or reapplied several times per day. A transfemoral amputee preparing the shrinker sock over the donning tube is shown in Figure 17-4. Figure 17-5 illustrates the donning of a shrinker sock with a donning tube.

Goals for Progression to Phase II

Patient and provider goals for the first phase of rehabilitation include but are not limited to the following:

- achieve independent bed mobility (turning over and sitting up),
- acquire the ability to correctly contract transversus abdominis and perform level-1 exercises for at least 3 minutes,
- maintain independent sitting balance for at least 1 minute,
- prevent contractures and other complications, and
- perform at least 10 minutes of cardiovascular exercise.

Figure 17-12. (**a–c**) Elizabeth Painter assists as Joshua Bleill, a bilateral transfemoral amputee, picks an object off the floor using cane support.

PHASE II. PREPROSTHETIC PHASE

The preprosthetic phase is the second phase of amputee rehabilitation and typically begins when the patient is discharged to an outpatient status and is characterized by independence with mobility and ADLs. The patient has usually undergone final closure of the residual limb(s) and prosthetic casting pending the removal of sutures.

Figure 17-13. Christopher Millward, a transtibial amputee, performs ladder walking drills.

Functional Activities

Encouraging community reintegration activities as soon as possible after amputation surgery helps speed recovery in several ways. First, it will offset the negative effects of immobility by promoting movement through the joints, muscle activity, and increased circulation. Second, the amputee may begin to reestablish his or her independence, which may be perceived as threatened because of the loss of limb. Third, the psychological advantage derived from activity and independence will impact the amputee's motivation throughout rehabilitation.

Flexibility

Amputees who have already lost ROM may benefit from many of the traditional therapy procedures such as passive ROM, active ROM, contract-relax stretching, soft tissue mobilization, myofascial techniques, joint mobilization, and other methods that promote increased ROM. Daily ROM and stretching exercises should be performed at the beginning of each rehabilitation session so that the routine is developed and carried over after discharge. Few differences exist between stretching activities for lower limb amputees and those stretches prescribed to nonamputees. The shorter residual limb—especially with transfemoral amputees—allows the amputee to hold the limb and move into the stretch position. Handling of the residual limb also can help to desensitize the limb while maintaining joint motion.[35]

Hip flexor tightness must be addressed aggressively with bilateral transfemoral amputees to minimize restriction of hip extension. A sustained stretching program coupled with the core strengthening exercises described previously will help maintain a neutral pelvis. Figure 17-6 shows examples of stretching a bilateral transfemoral amputee's hip while maintaining a neutral spine.

Strengthening

Dynamic Stump Exercises

Dynamic stump exercises only require a towel roll and step stool.[29,36] These exercises offer additional benefits aside from strengthening, such as desensitization, improving bed mobility, and maintaining joint ROM. While lying on an exercise mat the patient is asked to depress the residual limb into the towel roll by raising his or her pelvis off the surface for 10 seconds. The

four postural positions that strengthen the hip musculature include (1) prone for the hip extensors, (2) side lying for hip abductors, (3) side lying opposite side for adductors, and (4) supine for hip flexor muscles. As strength improves, resistance can be increased by placing cuff weights over the patient's hip or have him or her wear a weighted vest.[35] Figure 17-7 shows examples of dynamic stump exercises for a bilateral transfemoral amputee.

Patients with transtibial limb loss can initially perform short arc quad exercises with or without the addition of resistance such as a cuff weight. Other exercises for the hip and knee musculature include performing a straight leg raise in prone, supine, and side-lying positions. Again, as strength improves a cuff weight can be used to increase resistance. Implementation of CKC strengthening for the prosthetic side limb musculature can be difficult before receiving a prosthesis. Electrical stimulation can be used to enhance quadriceps muscle reeducation and recruitment.

As the amputee progresses, strengthening must be performed in multiple planes of motion. For example, the patient can perform hip strengthening exercises for abduction, extension, flexion, and adduction incorporating components of both isometric and isotonic contractions in the standing position. Resistance can be applied to the exercise leg with manual resistance, resistive bands, or cable/pulley weight machines. Progressive resistance exercises may be augmented by having the patient perform isometric contractions at end range to facilitate fatiguing of the contracting muscle group. The stance limb will also benefit from this mode of strengthening because stability must be achieved through the stance limb as the contralateral exercising limb performs the resisted movements. This

Figure 17-14. Luke Shirley, an upper and lower limb amputee, uses the elliptical trainer.

Figure 17-15. Joshua Bleill, a bilateral transfemoral amputee, performs weighted ball swings to promote standing dynamic balance assisted by Matthew Scherer.

Figure 17-16. Joshua Bleill, a bilateral transfemoral amputee, performs resisted diagonal patterns to promote standing dynamic balance assisted by Matthew Scherer.

mode of training is particularly useful in promoting functional stability in the patient with transfemoral limb loss.

Semisupine Resisted Pelvic Rotation Drills

Early preparation for resistive pelvic rotation during gait can be performed using resisted pelvic rotation drills. For proper execution of this drill, the patient should assume a semisupine position with his or her back partially supported with pillows or a bolster and the torso rotated to about 45 degrees between supine and side lying. The patient's pelvis should remain free and not blocked with pillows to allow movement within the full range of rotation at the hips. In the correct starting position, the patient will be facing the therapist who is kneeling next to him or her. The therapist will assume hand placement at the anterior superior iliac spine on the side of the pelvis to be trained (the side not in direct contact with the treatment table, see Figure 17-8). The therapist's other hand will prepare for positioning posterior to the iliac crest to provide cueing and counter resistance during the return phase of movement. To initiate the drill, the patient is cued to actively and forcefully rotate the anterior superior iliac spine into the therapist's anterior hand placements, allowing the patient to train disassociation of pelvic rotation with respect to shoulder girdle rotation (shoulders are still supported and stabilized by the mat and pillows allowing the pelvis to rotate freely). When the patient has overcome applied resistance through the complete range, counter cueing will be applied posterior to the ipsilateral iliac crest to initiate movement along the same rotational axis back to the starting position. Multiple repetitions of this drill performed with prosthetic limb(s) on or off can provide the patient with effective motor cues immediately before resistive gait training in the parallel bars and can be very effective in teaching patients who have difficulty with pelvic rotation during gait. A semisupine resisted pelvic rotation drill is illustrated in Figure 17-8.

Figure 17-17. Joshua Bleill, a bilateral transfemoral amputee, performs pull-ups to promote upper body strength.

Figure 17-18. Elizabeth Painter assists Luke Shirley, a transfemoral amputee, with performing a stool stepping exercise to promote single limb standing balance.

Figure 17-19. Elizabeth Painter assists Luke Shirley, a transfemoral amputee, with resisted gait training to promote pelvic rotation.

Figure 17-20. Elizabeth Painter assists Luke Shirley, a transfemoral amputee, with passive trunk rotation to improve balance during ambulation.

Progressive Resistive Exercise for Uninvolved Limbs

Access to isotonic strengthening equipment can be a tremendous advantage because of the numerous benefits derived from these forms of strengthening. There are few modifications in patient positioning on the weight machines and with most free weight programs. Moreover, this form of strengthening is very familiar to amputees who lifted weights before their injuries. When prescribing a program it is important to include the amputees in the exercise selection and choose familiar exercises. When they are ready, let them perform their general strengthening program with other amputees as they typically would with their unit. The sense of independence and ownership in their rehabilitation program can have lasting effects well beyond general strength increases. Figure 17-9 illustrates a bilateral transfemoral amputee performing unsupported push-ups.

Core Stabilization

Amputees are not always able to rely on proprioceptive feedback, ankle strategies, knee strategies, or sometimes hip strategies to help them stand, balance, and ambulate. They must rely on visual, somatosensory, vestibular, and lumbopelvic stability cues to effectively function. It continues to be important in this phase to progress core stabilization exercises to maintain trunk strength, decrease the possible risk of back pain, and assist in the reduction of gait deviations associated with the trunk.

Progression of core stabilization exercises occurs when level-1 exercises are mastered; endurance has improved; and the patient can perform at least one level-1 exercise for 3 minutes with good form/neutral spine, minimal cueing, and loaded postures are tolerated. Examples of more challenging core stabilization exercises include the following:

- sitting on dynamic disc and moving arms/legs,
- therapist performing rhythmic stabilization,
- prone superman,
- supine "dead bug,"
- advanced exercise ball bridging,
- prone with heavier weights, and
- medicine ball drills.

Figure 17-22. Christopher Millward, a transtibial amputee, works on rotational stability and eccentric lower limb control while on a dynamic surface.

Figure 17-21. A ceiling suspension device is used during ambulation with Marco Robledo, a transfemoral amputee who is first learning to walk with a cane assisted by Matthew Scherer.

Figure 17-23. Two amputees, Christopher Millward and Chad Watson, work as partners to develop dynamic core stability and lower limb control.

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Figure 17-24. (**a–e**) Christopher Millward, a transtibial amputee, performs plyometric spot drills performed to increase lower limb strength, speed, and agility.

Cardiovascular Endurance

Because of the severity of injuries many SMs sustain and the deconditioning that occurs as a result of the prolonged postoperative periods, cardiovascular conditioning is compromised in many of the lower limb amputees. Cardiovascular endurance training can have a direct effect on the functional walking capabilities with regard to distance and assistive device required to ambulate.[37–39] The ability to improve overall ambulation capabilities with aerobic training applies to all levels of amputation.[39] Throughout the rehabilitation program cardiovascular fitness should be incorporated into every treatment plan. Progressing the amputee from the UBE to the lower limb ergometer can begin as early as their sitting balance and wounds permit. Once the ability to stand with the prosthesis(es) is achieved, balance training can be incorporated by standing on a compliant surface while working the arms with the UBE (Figure 17-10). Often single limb cycling with the nonamputated limb is introduced early in the rehabilitation program. Swimming, hand cycling, and rowing can also be encouraged once the wounds are healed and the amputee is ready for more dynamic training away from the rehabilitation gym.

Goals for Progression to Phase III

Patient and provider goals for the second phase of rehabilitation include but are not limited to the following:

- independence with prescribed therapeutic exercises in strengthening, core stability, balance, and cardiovascular conditioning;
- functional range of motion of the lower limb joints to allow optimal gait training with the use of prosthetic device(s); and
- independence with ambulation with appropriate assistive device (without prosthesis).

PHASE III. PROSTHETIC/AMBULATION PHASE

The prosthetic/ambulation phase is the third phase of rehabilitation and begins when the amputee receives his or her prosthesis(es) and is medically cleared by the physician to begin weight bearing on the amputated limb. Healing of the residual limb permits the amputee to begin weight bearing as tolerated. Initially the amputee focuses

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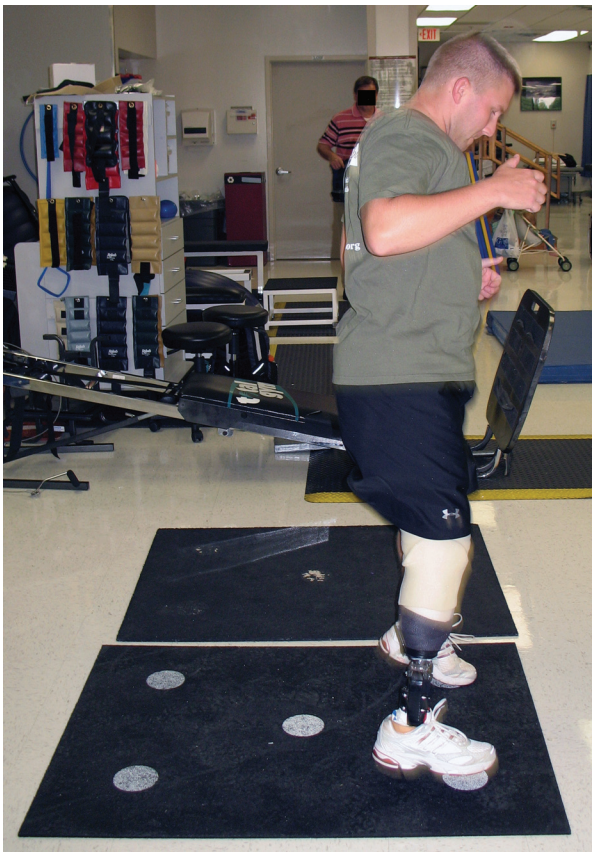

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on reestablishing standing balance that would include the ability to transfer weight equally between both limbs and maintain single limb stability over the prosthetic limb(s). Prosthetic gait training includes movement re-education for a symmetrical gait and ambulation with the appropriate assistive device. As proficiency with the prosthesis improves, functional activities such as stairs, curbs, ramps, and uneven terrain may be introduced.

Functional Activities

Falls/Recovery

Falling or lowering oneself to the floor is an important skill to learn not only for safety reasons, but also as a means to perform floor level activities. During falling the amputee must first discard any assistive device to avoid injury. Amputees should land on their hands with the elbows slightly flexed to dampen the force and decrease the possibility of injury. As the elbows flex, the amputee should roll to one side, further decreasing the impact of the fall.

Figure 17-25. (**a–c**) Matthew Scherer assists Christopher Millward, a transtibial amputee, with plyometric depth jumps to increase lower limb power and prosthetic control.

Lowering the body to the floor in a controlled manner is initiated by squatting with the sound limb followed by gently leaning forward onto the slightly flexed upper limbs. From this position the amputee has the choice of remaining in quadruped or assuming a sitting posture.

Floor to Standing. Many techniques exist for teaching amputees how to rise from the floor to a standing position. The fundamental principle is to use the assistive device for balance and the sound limb for power as the body begins to rise. Depending on the type of amputation and the level of skill, the amputee and therapist must work closely together to determine the most efficient and safe manner to successfully master this task.

Stairs

Ascending and descending stairs is most safely and comfortably performed one step at a time (step-by-step). A few exceptional transfemoral amputees can descend stairs step-over-step. Most transtibial amputees have the option of either method, although hip disarticulation and hemipelvectomy amputees are limited to the step-by-step method.

Step-by-Step. This method is essentially the same for all levels of amputees. When ascending stairs, the body weight is shifted to the trailing prosthetic limb as the leading sound limb firmly places the foot on the stair. The trunk is slightly flexed over the sound limb as the knee extends raising the prosthetic limb to the same step. The same process is repeated for each step. One of the primary goals for ascending stairs step-over-step is to increase the ascent speed. To decrease the effort and increase safety, the easiest method to increase ascent speed is to skip a step. The amputee simply skips a stair with the leading sound limb and raises the body placing the prosthetic limb on the same step.

When descending stairs, the body weight is shifted to the sound limb as the prosthetic limb is lowered to the step below by eccentrically flexing the knee of the sound limb. Once the prosthetic limb is securely in place, the body weight is transferred to the prosthetic limb and the sound limb is lowered to the same step.

Transfemoral Amputees: Step-over-Step. Timing and coordination become critical factors in executing stair climbing step-over-step. As the transfemoral amputee approaches the stairs, the prosthetic limb is the first to ascend the stairs by rapid acceleration of hip flexion to clear the step. With the prosthetic foot firmly on the step, the residual limb must exert a great enough force to fully extend the hip so that the sound foot may advance to the step above. As the amputee advances to the next step, the sound side hip extends and the prosthetic side hip must once again flex at an accelerated speed to achieve sufficient knee flexion to place the prosthetic foot on the next step above.

Descending stairs is achieved by placing only the heel of the prosthetic foot on the stair below, then shifting the body weight over the prosthetic limb, thus, passively flexing the knee. The sound limb must quickly reach the step below in time to catch the body's weight. The yield rate control of the prosthetic knee will dictate the speed of descent, but the key to most knee systems is maintaining body weight over the prosthesis. The process is repeated until a rhythm is achieved.[29] Most transfemoral amputees who have mastered this skill descend stairs at a fast pace, so the therapist should consider if the speed of descent is safe for each individual (Figure 17-11).

Transtibial Amputees: Step-over-Step Stairs. When ascending stairs transtibial amputees that do not have the ability to dorsiflex their foot/ankle assembly must generate a stronger concentric contraction of the knee and hip extensors to successfully transfer their body weight over the prosthetic limb.

Descending stairs is very similar to normal descent with one exception: only the prosthetic foot heel is placed on the stair. This compensates for the lack of dorsiflexion within the foot/ankle assembly.[29]

Picking up Objects

Single limb balance and bending to pick objects off the floor is taught during the early stages of rehabilitation for crutch walking, hopping, and other skills. Single limb squatting is considerably more difficult but can help improve balance and strength. When first attempting this skill, half squats with a chair underneath the amputee are recommended. Progression from picking larger objects off the floor to smaller objects requires deeper or lower squats (Figure 17-12).

Core Stabilization, Closed Kinetic Chain Exercises, and Balance/Proprioception

Core stabilization exercises in Phase III may be progressed to include standing and more challenging balance activities. The same principles apply: maintain neutral spine, correctly draw in the lower abdominal wall, and work on endurance. Core strengthening occurs while also performing CKC strengthening and balance exercises. Examples in this phase follow:

- standing on foam or DynaDiscs (Exertools, Rohnert Park, Calif);
- cone walking;
- single leg balance on either limb/steamboats;
- medicine ball exercises in standing, sitting, prone, or supine exercise ball progression;
- Plyoback (Exertools, Rohnert Park, Calif) training with increasing weight;
- wall squats;
- quadrant and plane stepping activities;
- ball rolling with sound limb;
- ladder walking drills (Figure 17-13); and
- elliptical trainer or stair stepper (Figure 17-14).

Bilateral lower limb amputees will benefit from standing and dynamic balance activities. Therapeutic interventions designed to improve core stability in standing include diagonal movements with resistance cables or medicine balls (Figure 17-15, Figure 17-16, and Figure 17-17). Functional challenges may include similar activities performed outside on grassy surfaces.

Figure 17-26. (**a–e**) Chad Watson, a transfemoral amputee, performs a series of weapon drills to prepare to return to active duty.

Weight-Shifting Progression

Orientation of the COM over the BOS to maintain balance requires that the amputee become familiar with these terms and aware of their relationship. Learning to shift the COM over one foot and then the other will assist with lateral displacement of the COM. As the displacement from side to side increases, amputees should take their sound side hand off the parallel bars and eventually both hands off the parallel bars. Increased weight bearing will be a direct result of improved COM displacement and will establish a firm foundation for actual weight shifting during ambulation.[29]

Standing Progression with Prosthetic Limb

Single limb balance over the prosthetic limb while advancing the sound limb should be practiced in a controlled manner so that when called to do so in a dynamic situation, such as walking,

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this skill can be used with relatively little difficulty. The stool stepping exercise is an excellent method in which this skill may be learned.[32] The amputee should stand in the parallel bars with the sound limb in front of a 10- to 20-centimeter high stool (or block). The height depends on the ability level. The amputee should step slowly onto the stool with the sound limb while using bilateral upper limb support on the parallel bars (Figure 17-18). To further increase these weight-bearing skills, the amputee should remove the sound side hand from the parallel bars and then eventually the other hand. Initially, the speed of the sound leg will increase when upper limb support is removed. However, with practice the speed will become slower and more controlled, thus promoting increased weight bearing on the prosthesis.[29]

Figure 17-27. A transfemoral/transradial amputee performs prone position weapons training in the firearms training simulation center to prepare to return to duty.

Ambulation

Once the amputee has the base strength and balance, resistive gait training techniques are implemented to reeducate the amputee to the normal gait movements necessary to maximize prosthetic performance and promote economy of gait.[29,40] Advanced gait training exercises are also offered to assist the amputee to negotiate environmental conditions that require multidirectional movements and superior dynamic balance.

Pelvic Rotation

To restore the correct pelvic motion, resistive gait training for lower limb amputees has been demonstrated to improve balance and normalize gait.[29,40] Restoration of pelvic rotation requires that the therapist use rhythmic initiation through the anterior superior iliac spines, giving the amputee the feeling of rotating the pelvis forward as passive flexion of the prosthetic knee occurs. The amputee will gradually begin to actively rotate his or her pelvis during this time. The therapist can gradually progress from active assistive motions to resistive while continually facilitating proper motion of the pelvis and prosthesis (Figure 17-19). Once the therapist is satisfied with pelvic motions, the amputee progresses to the swing phase of gait stepping forward and backward with the prosthetic limb.

When both the therapist and the amputee are comfortable with the gait demonstrated in the parallel bars, the same procedure as described above is practiced out of the parallel bars with the amputee initially using the therapist's shoulders as support and progressing to both hands free when appropriate. The therapist may or may not continue to provide proprioceptive input to the pelvis.

Trunk Rotation and Arm Swing

During human locomotion, the trunk and upper limb rotate opposite to the pelvic girdle and lower limb. Trunk rotation is necessary for balance, momentum, and symmetry of gait. Arm swing, which provides balance, momentum, and symmetry of gait, is directly influenced by the speed of ambulation.[29,41] As the walking speed of gait is accelerated, arm swing increases, thus permitting a more efficient gait.

Many amputees have a decreased trunk rotation and arm swing, especially on the prosthetic side. This may be the result of fear or lack of confidence when walking with the prosthesis. Returning trunk rotation and arm swing is easily accomplished by utilizing rhythmic initiation or passively cueing the trunk as the amputee walks. The therapist stands behind the amputee with one hand on either shoulder. As the amputee walks the therapist gently rotates the trunk. When the left leg steps forward the right shoulder is rotated forward and vice versa. Once the amputee feels comfortable with the motion, he or she can actively take over the motion[29] (Figure 17-20).

Stride Length, Width, and Cadence

As the amputee begins to ambulate independently, verbal cueing may be necessary as a reminder to keep the sound foot away from mid-line to maintain the

Figure 17-28. Computerized simulation allows amputees to begin preparation for weapons-related activities.

Figure 17-29. (**a–c**) Matthew Scherer performs a Dix-Hallpike maneuver on Marco Robledo, an amputee with benign paroxysmal positional vertigo.

proper BOS. Maintenance of equal stride length may not be immediately forthcoming because many amputees tend to take a longer step with the prosthetic limb than the sound limb. When adequate weight bearing through the prosthetic limb has been achieved, the amputee should begin to take longer steps with the sound limb and slightly shorter steps with the prosthetic limb. This principle also applies when increasing the cadence. When an amputee increases his or her speed of ambulation, the prosthetic limb often compensates by taking a longer step, thus increasing the asymmetry. By simply having the amputee take a longer step with the sound limb and a moderate step with the prosthetic limb, increased speed of gait is accomplished without increased asymmetry. As balance and confidence and symmetry in stride length improve, the amputee's cadence will increase.[29]

Assistive Devices and Gait Training

Amputees who will be independent ambulators and those who will require an assistive device can benefit from the above systematic rehabilitation program. Most patients can be progressed to the point of ambulating out of the parallel bars. At that time, the amputee must practice ambulating with the chosen

Figure 17-30. (**a–b**) Marco Robledo is a traumatic brain injury patient with a unilateral transradial amputation and a unilateral transfemoral amputation.

assistive device and maintaining pelvic rotation, adequate BOS, equal stance time, and equal stride length, all of which can have a direct influence on the energy cost of walking. Trunk rotation would be absent with amputees utilizing a walker as an assistive device; however, those ambulating with crutches or a cane should be able to incorporate trunk rotation into their gait. Amputees will also find ceiling suspension tracks useful for early ambulation when developing confidence with the prosthesis and assistive device (Figure 17-21).

Resistive Rollover Drills

Inability to roll over the prosthetic foot during late stance phases can lead to asymmetrical gait patterns. Therapists can facilitate more efficient rollover on the prosthetic foot by cueing the patient to push into a cane held in both hands at waist level by both the therapist and the patient. During this drill, the therapist and patient face one another with the therapist's back to the direction of movement. The therapist applies mild to moderate resistance to the cane beginning at mid-stance on the prosthetic side. The patient must overcome this resistance while maintaining upright posture throughout the late stance. The therapist can vary resistance to the patient during the rollover phase, thereby enhancing proprioceptive feedback in the residual limb, core recruitment, and balance.

Excessive Lateral Trunk Movement

Patients with knee disarticulation and transfemoral amputations commonly present with excessive lateral trunk lean over the prosthetic side limb(s) during ambulation. Decreased force production by the hip abductors secondary to decreased length of femur may be compensated for by increased lateral trunk lean over the prosthetic stance limb. Strengthening the hip musculature with emphasis on the hip abductors may increase single leg stance stability. CKC exercises and resistive gait training may help reduce lateral trunk lean over the prosthetic side limb.

Multidirectional Movements—Sidestepping

Sidestepping, or walking sideways, can be introduced to amputees at various times throughout their rehabilitation. Amputees can begin with simple weight shifting in the parallel bars and later perform higher level activities such as unassisted sidestepping around tables or a small obstacle course that requires many small turns. During early rehabilitation this skill provides amputees with a functional exercise for strengthening the hip abductors, and later in the rehabilitation process, an opportunity to progress into multidirectional movements.

Multidirectional Movements—Backward Walking

Walking backward is not difficult for transtibial amputees but it does pose a problem for amputees requiring a prosthetic knee because they cannot actively flex the knee for adequate ground clearance. The most comfortable method of backward walking is by vaulting upward (plantarflexing) on the sound foot to obtain sufficient height so that the prosthetic limb that is moving posteriorly can clear the ground.

Goals for Progression to Phase IV

Patient and provider goals for the third phase of rehabilitation include but are not limited to the following:

- able to tolerate progressive weight-bearing and weight-shifting activities;
- independent with Phase III rehabilitation drills and exercises;
- minimal gait deviations that are not worsened with higher level activity;
- independent with falls recovery;
- progressing ambulation to modified independence or independence with appropriate assistive device over level surfaces, inclines, and stairs;
- able to transition from standard foot to a high energy foot for those with transtibial amputation; and
- able to start pre-running drills in free swing mode (microprocessor knee) with progression to running drills in mechanical knee for those with a transfemoral amputation.

PHASE IV. PROGRESSIVE ACTIVITIES /RETURN TO ACTIVE DUTY PHASE

The progressive activities / return to active duty phase is the fourth phase in which amputees specifically train for and return to recreational and sporting activities, and for those who wish to remain on active duty. The active duty military population will typically set goals of achieving the highest level of physical function possible regardless of the extent of their injuries. Their unique qualities include young age, good health before injury, and high motivation. As a result, many SMs have raised the bar of expectations traditionally held by rehabilitation professionals for young people with limb loss.

Walter Reed Amputee Patient Care team policy stipulates that patients undergo a total body Dexa Scan (hip, spine, residual limb) to assess overall fracture risk (osteopenia / osteoporosis) due to rapid bone loss in proximal amputated limb (proximal portion of an amputated limb) or other extremities that have been partial or nonweight bearing for prolonged periods of time (eg, from external fixaters). The bone density must be within normal limits before receiving an advanced running prosthesis.

Recreational/Sports Activities

Agility, sports-specific drills, and strength training continue to be an important part of rehabilitation. The sports medicine model is used to prepare amputees for an active lifestyle. Agility drills and strengthening exercises that are geared toward specific sports or recreation are practiced individually or in group sessions. In addition, training for hand crank cycling, SCUBA, and kayaking are provided to those who wish to participate.

Core Stabilization

By Phase IV, core stabilization should be incorporated into all agility, sports-specific drills, strength training, plyometrics, balance, and proprioception activities (Figure 17-22). Plyometrics begin when the residual limb(s) can withstand the forces during this training for power enhancement. Rotational drills with medicine balls are frequently performed with a partner or as group exercises (Figure 17-23). Other advanced core stabilizing exercises in this phase include balancing while standing on a DynaDisc (Exertools, Rohnert Park, Calif), using an exercise ball during single leg wall sits, single leg balance with perturbations, plyometric jumps, and other higher level exercises (Figure 17-24 and Figure 17-25). Amputees are verbally reminded to maintain a strong core by sustaining a regular exercise program to help prevent secondary health conditions such as low back pain and to enhance physical performance.

Military Task Training/Military Operations

Although not every amputee wishes to return to active duty, those that do will have the option of participating in military specific tasks before returning to their units. Performing military specific tasks and drills with a prosthesis(es) can be difficult initially; however, learning the "tricks" of prosthetic use can often make the difference for success. Amputees must meet the established criteria for a warrior and successfully perform common tasks to remain on active duty. The training requirements and preparation will be even greater for those amputees who seek to return to an operations type unit. Examples of military task training that can be incorporated into rehabilitation include but are not limited to the following:

- road marching;
- rescues and buddy carries;
- reaction drills;
- site picture drills and room clearing drills; and
- physical fitness test training such as push-ups, sit-ups, and running.

Road Marching

Tasking an amputee to march with a weighted rucksack over a prescribed distance challenges dynamic postural stability, ambulation tolerance, cardiovascular reserves, residual limb integrity, and prosthetic capabilities. Distance and cadence should be progressed as tolerated by the amputee.

Rescues and Buddy Carries

Amputees can be challenged to carry or extract fellow SMs using various carrying or extraction techniques to simulate such tasks in an operational environment. Drills with weights and heavy sacks should be practiced initially to develop movement skills with the prosthesis(es), progressing to live maneuvers with a partner when appropriate.

Immediate Action Drills and Reacting to Contact

Reaction drills require quick transitions from standing to kneeling, kneeling to supine, back up to standing, and advancing with a simulated weapon.

Site Picture Drills and Room Clearing Drills

Site picture drills and room clearing drills simulate movement in tactical environments to include urban terrain with a simulated weapon either aimed or "at the ready" in preparation for deployment. These basic drills can be progressed by challenging an amputee's ability to negotiate uneven terrain, compliant surfaces, and obstacles while maintaining an operational posture and efficient and effective continuous forward movement (Figure 17-26).

Firearms Training Simulator Centers

Firearms training simulator centers, which are located within military training facilities, allow amputees the opportunity to reestablish firearms qualifications with various weapons using video simulation (Figure 17-27 and Figure 17-28). Physical therapists work closely with occupational therapists and the firearms training simulator trainer to promote ADLs by training amputees who stay on active duty and/or have the vocational/leisure interest in recreational activities such as hunting or skeet shooting. Specialized terminal devices, adaptive techniques, and hand or eye dominance retraining can all be incorporated for enhanced experiences. Improving basic firearm skills with these modifications allows amputees to succeed and improve their confidence.

Special Considerations for Amputees with Comorbidities and Multiple Limb Loss

Comorbidity Considerations

Overcoming the challenges of limb loss can be complicated by the effects of comorbidities including soft tissue injuries and abdominal injuries, fractures, peripheral nerve injuries, vestibular pathology, and TBI. Varying degrees of severity of these conditions can significantly affect early weight bearing, mobility, tolerance for rehabilitation, and potentially even the ability to concentrate and follow commands. All interdisciplinary team members have a role in evaluating, treating, and advising their colleagues on comorbid conditions, the resultant level of the patient's functionality, and how this clinical picture should be best managed.

Abdominal/Visceral Trauma

Patients with external stomas will require the assistance of a wound care nurse for initial patient and family member education. They will not be allowed prone for stretching or conditioning exercises. Therefore, great care must be taken to ensure that transfemoral amputees use alternate hip flexor stretching techniques (side lying or supine with leg off edge of bed) in preparation for gait training.

Fractures

Patients with fractures in one or more limbs, the pelvis, or vertebrae will likely have weight-bearing restrictions that will affect their mobility and ability to participate in certain types of therapeutic exercise. It is not uncommon for polytrauma patients to bear weight on their prosthetic side before their fractured contralateral lower limb. Although devices such as external fixators may stabilize comminuted fractures and allow for earlier weight bearing, they are often painful and require diligent pin care to guard against infection. Those patients with fractured upper limbs will be limited in the use of their upper limbs for transfers, ADLs, and upper limb muscular endurance and resistance training. Fractures in the pelvis or the vertebrae will limit the patient's ability to sit, participate in gait training, and perform CKC strengthening and conditioning.

Peripheral Nerve Injuries

Patients with limb loss may have to contend with the effects of peripheral nerve injuries in residual upper or lower limbs. For example, deep and superficial fibular nerve injuries from blast shrapnel on the "sound side" limb can cause difficulty or the inability to effectively dorsiflex the foot during gait, necessitating the use of an ankle foot orthosis. Similarly, upper limb injuries to the radial, median, or ulnar nerves can affect a patient's ability to perform ADLs, transfer independently, or even operate a power wheelchair.

Vestibular Insult

Although the incidence of vestibular pathology across the broad spectrum of polytrauma patients is unknown, blast injury survivors with limb loss often present with vestibular deficits such as benign paroxysmal positional vertigo and vestibular hypofunction.[42] Vestibular dysfunction can diminish rehabilitation tolerance, affect static and dynamic balance, and increase risk of falls during ambulation. Early management of these conditions may include use of the Canalith Repositioning Maneuver for benign paroxysmal positional vertigo or adaptation, substitution, and habituation exercises for unilateral or bilateral vestibular hypofunction. Early and aggressive static and dynamic balance training and gait training can help patients compensate for vestibular deficits as they work through vestibular rehabilitation. Figure 17-29 demonstrates the Dix-Hallpike maneuver being performed on an amputee with benign paroxysmal positional vertigo.

Traumatic Brain Injury

Amputees with TBI must be assessed for the severity of their brain injury before the initiation of the standard rehabilitation protocol. Patients' ability to attend to tasks and participate in therapy usually dictates whether they are appropriate candidates for polytrauma rehabilitation immediately or whether they should be first managed by the Veterans Affairs Healthcare System for more intensive neurological rehabilitation and neuropsychological needs. Amputees with mild TBI may present with balance deficits, vestibular pathology, difficulty with learning (or relearning) motor tasks, and changes in affect. These deficits can complicate the typical course of rehabilitation and interventions should be incorporated into the overall plan of care to address them. Although numerous other conditions complicate a patient's ability to participate in full spectrum amputee and polytrauma rehabilitation, the aforementioned are among the most common. It is imperative to document all pathologies, impairments, and functional limitations so that they can be prioritized and addressed in the interdisciplinary plan of care. Figure 17-30 shows a patient with a TBI, a unilateral transradial amputation, and a unilateral transfemoral amputation undergoing physical therapy.

Special Considerations for the Patient with Multiple Limb Loss

Since the initiation of hostilities in Iraq and Afghanistan the incidence of bilateral lower limb loss is 18%.[43] For patients with bilateral lower limb loss prosthetic and rehabilitation management continues to improve because of increased attention to this population of amputees. The attachment at the end of this chapter displays the bilateral transfemoral amputee protocol.

The altered anatomy of a bilateral lower limb amputee offers additional considerations when planning a standing and gait training program. For example, the physical therapist may observe increased lordosis during standing, loss of balance strategies, and altered postural stability. These considerations can contribute to reduced standing or dynamic balance and the increased possibility of falls. Thus, the importance of initiating core and postural stability exercises early in the rehabilitation program is even more pronounced for the bilateral lower limb amputee. Furthermore, it is essential to perform thorough vestibular assessments and TBI

screening to document and address any neurologic impairments that may contribute to balance reduction.

The use of low profile prosthesis or "stubbies" can assist bilateral transfemoral amputees with learning to use their hip and trunk musculature. Stubbies by design lower the COM closer to the BOS, therefore requiring less muscular effort to maintain standing balance. Although body image can be an issue for some patients, the early bipedal locomotion and increased mobility in most instances outweigh the body image issues. Other benefits identified with use of stubbies include facilitating early weight-bearing activities in the parallel bars, achieving improved weight shifting during ambulation, assisting in the development of core stability and postural stability, and decreasing the risk of falls with early ambulation training in the clinic.

SUMMARY

Rehabilitative care of SMs with limb loss has evolved from the elementary goal of healing wounds and returning home to a comprehensive rehabilitative philosophy: restoration of function to the highest possible degree. The multifaceted rehabilitation programs go beyond daily activities and mobility training to include the opportunity to train for return to duty, vocational preparation, sports, or other leisure activities. The US military's four-phase program of functional progressive rehabilitation for wounded SMs with lower limb loss presented in this chapter is designed to promote a rehabilitation philosophy of treating the amputee as a "tactical athlete" applying the highest level training similar to that of sports medicine rehabilitation. The four-phase rehabilitation program includes (1) initial management, (2) preprosthetic, (3) prosthetic/ambulation, and (4) progressive activities/return to active duty. Within each phase of rehabilitation evidence-based rehabilitation techniques and innovative exercise applications are applied with the goal of maximizing the rehabilitation potential of every amputee. The information in this chapter presents the most current rehabilitation techniques and philosophy in an ever evolving process of providing the best care possible.

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ATTACHMENT: MILITARY AMPUTEE REHABILITATION PROTOCOL

Note: Each surgeon has preferred methods or guidance that may deviate from the below stated recommendations based on the specifics of the case or other parameters. This protocol should not be used in lieu of clear and regular communication between attending surgeon and the patient's physical therapist.

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AMPUTEE REHABILITATION

Revised May 2007

Phase I: Protective Healing (Post-op Days 1–7)

Note: Exercise prescription is dependent upon the tissue healing process and *individual* functional readiness in *all* stages. If any concerns or complications arise regarding the progress of any patient, physical therapy will contact the orthopedist or physiatrist.

Immediate post-operative therapy focuses on bed mobility, transfers, wheelchair management and/or ambulation with appropriate assistive device (AD), therapeutic exercise for deconditioning, contracture avoidance, pain management assistance, and self-care.

Goals:
1. Restore functional mobility/basic ambulation
   - Bed mobility
   - Transfers (bedside chair/wheelchair)
   - Ambulation with appropriate AD
   - Wheelchair management
2. Teach appropriate residual limb management and self-care
3. Maintain/restore baseline conditioning and balance
4. Assist with pain management
5. Institute range of motion (ROM) and stretching exercises to avoid contractures
6. Address any potential barriers to rehabilitation at earliest opportunity

Cardiovascular
- Upper body ergometer
- Seated calisthenics

Functional Activities
- Bed mobility
- Rolling
- Transfers
- Wheelchair management/mobility

Range of Motion ***(see addendum for stretching and ROM restrictions during Phase I)***
- Contracture avoidance/stretching program (static, contract relax)
- Passive ROM
- Active Assistive ROM (AAROM) to tolerance
- Active ROM (AROM) as needed for activity

Strengthening ***(see Phase I addendum for restrictions by level during Phase I)***
- Isometrics—Quadriceps, Gluteals, Hamstrings
- Ankle pumps
- 3- or 4-way hip/sliding board (Abduction, Adduction, Flexion) Prone hip extension
- Lumbar stabilization (initiate instruction on Transversus Abdominis contraction)

Balance

- Seated mat
- Shifting on mat
- Sit to stand
- Stand in parallel bars
- Single leg balance

Gait

- Ambulate in parallel bars
- Ambulate with appropriate AD on level surfaces
- Ambulate with appropriate AD on unlevel surfaces

Phase I Addendum: Post Surgical Restrictions
During the acute phase of rehabilitation patients will need to be carefully monitored to ensure appropriate healing of the myodesis/ surgical repair. The following are guidelines established by the PT AMP section in accordance the primary lower extremity amputee surgeon.

Note that each surgeon has preferred methods or guidance that may deviate from the below stated recommendations based on the specifics of the case or other parameters. This protocol should not be used to the exclusion of clear communication between attending surgeon and the patient's physical therapist.

1. Partial foot amputations:
   - Heel Weight Bearing permissible.
   - Fit with shrinker ASAP to control swelling
   - No therapeutic exercise restrictions

2. Symes amputations:
   - Patients are casted x 2-3 weeks to stabilize the heel pad which is secured into the tibia. Non weight bearing for additional 3 weeks after the cast is removed (5 weeks NWB total).
   - Closed Kinetic Chain Exercises appropriate once casted (no distal end bearing in cast)
   - Expect delayed prosthetic fitting.

3. Transtibial amputations:
   - If myodesis is tenuous, the patient may be casted in knee flexion.
   - Hamstring stretching restricted x 2 weeks with tenuous myodesis. Otherwise, no therex restrictions.
   - CKC immediately if stabilization point on bolster is proximal to the myodesis.

4. Knee Disarticulation:
   - Patellar tendon is sewn into the ACL during surgery
   - Straight Leg Raise without weight x 2 weeks s/p surgery. No restrictions thereafter.
   - No restrictions to abduction or adduction therex.

5. Transfemoral amputations:
   - Myodesis of adductor magnus tendon secured to lateral femur during surgery.
     i. No active adduction strengthening exercises x 4 weeks,
     ii. No active abduction strengthening past neutral x 2 weeks (abduction to neutral from adducted posture is permissible)
     iii. No forward flexion x 2 weeks s/p myodesis to protect distal HS attachment
     iv. Bridging in supine is authorized (distal HS attachments are stabilized with proximal placement of bolster)

6. Hip Disarticulation:
   - No muscle attachments stressed with endbearing/ sitting on the hip disarticulation
   - No therex restrictions once wound healing complete for end bearing.

Phase II: Preprosthetic Training (Weeks 2–10)

Patient is likely recovering from final closure and emphasis is on preparation for the prosthesis. Phase II concentrates on continued limb management to include wrapping, don and doff shrinker, contracture avoidance, desensitization/pain management, cardiovascular endurance, balance and coordination, and ambulation with AD or wheelchair activities as appropriate.

Goals:
1. Independent with Phase I and Phase II exercises in the following areas of rehabilitation:
   - Strengthening
   - Core stability/lumbar stabilization
   - Balance
   - Cardiovascular conditioning
2. Independent with residual limb care and volume management
3. Sufficient ROM to allow optimal gait training with use of prosthetic device(s)
4. Independent with mobility and ambulation with appropriate AD(s)
5. Continue to assist with pain management

Cardiovascular
- Upper body ergometer
- Well leg bike
- Aquatic physical therapy when wounds well healed

Functional Activities
- Bed mobility
- Transfers
- Fall training
- Community re-integration
- Household activities

Range of Motion
- ROM progression as tolerated without other contraindications
- Continue contracture avoidance/stretching program
- Prone positioning, prone on elbows to prone press ups
- Scar massage

Strengthening/Lumbar Stabilization
- Isometrics
- Progressive resistive exercise of uninvolved extremities
- 4-way hip with weight progression
- Short arc quadriceps exercise with weight progression (if have painfree knee)
- Bridging
- Sky divers
- Crunches (with Transversus Abdominis contraction)
- Total gym squats
- Controlled dips
- Standing 4-way hip

Balance
- Sitting with PNF patterns (ball, resisted)
- Balance board or disk sitting
- Medicine ball catch
- Bolster under base of LE support
- Weight shift arms and legs
- Add perturbation or unstable base (Swiss Ball)
- Trunk stabilization
- Quadruped/Biped to push up (can use large round bolster)
- Wand trunk rotations with/without weights
- Diagonal movements

Gait
- Ambulation with assistive device
- Unlevel surfaces, uneven terrain, ramps

Phase III: Prosthetic Training (Weeks 11– 20)

During this phase the patient learns to use the prosthesis. Initially the amputee focuses on weight shifting and weight bearing, normalizing mechanics of available joints and motion (trunk, pelvic, hip), and ambulation with various assistive devices and prosthesis.

Goals:
1. Progressive weight bearing and weight shifting activities
2. Independent with Phase III rehab drills and exercises
3. Normalize gait
4. Progress gait to modified independence or independence with appropriate AD

Cardiovascular
- Upper body ergometer
- Calisthenics
- Bike
- Swim
- Circuit training
- Treadmill walk
- Stairmaster/Elliptical Trainer

Functional Activity
- Prosthesis management
- Picking up objects
- Stepping up curbs/ramps/hills/stairs
- Floor to chairs, floor to stand, stand to floor transfers
- Falling/ falls recovery strategies

Range of Motion
- Contracture avoidance
- HEP stretching program

Strengthening
- Upper/Lower extremity progressive resistive exercise and general strength conditioning
- Closed chain: wall squats, step ups, quadrant and plane stepping activities, steamboats, ball rolling with sound limb, trunk stabilization
- Isokinetics

Balance
- Sitting Swiss ball with activities
- Standing with prosthesis: weight shift forward, backward, lateral with progression to diagonal
- Weight shifting on soft surface
- Rocker board
- Ball rolling with sound limb
- Balance recovery
- Single leg stepping
- Single leg balance

Gait
- Component training: pelvic rotation, knee flexion
- Single leg to well leg step
- Stride width, length, cadence
- Trunk rotation
- Ambulate in parallel bars
- Ambulate with walker/crutches/canes level surfaces
- Treadmill walk

Progression
- Sideways walk
- Tandem walk
- Backward walk
- Multiple prostheses (C-leg, mechanical)

Phase IV (Months 3 – 6)

Return to progressive activities is where patients return to recreational activities and prosthetic use. For most of our population active duty military have a high level of activity prior to amputation. For others return to prior activity level may be household and family daily activities.

Goals:
1. Return to high level/ high impact conditioning activities (agility drills, lower extremity plyometrics and ladder drills)
2. Initiate the return to run protocol (Transfemoral/Transtibial)
3. Return to organized and individualized sport activity utilizing developed conditioning, balance and running training base.
4. Return to vocation or MOS specific skill and task training

Cardiovascular
- Activity specific
- Walking
- Upper body ergometer
- Bike/Stairmaster/Elliptical Trainer

ROM
- Home exercise program for maintenance
- Stretching

Strengthening
- Progressive resistive exercise for overall strengthening program
- Closed chain with prosthesis
- Trunk and core strengthening

Balance
- Bilateral standing on rocker board
- Single leg standing with progressive perturbation, unlevel surfaces with ball/bodyblade
- Single leg hops
- Agility drills
- Climbing

Gait
- Progressive run/walk

Functional and Sport Specific Drills
Plyometrics
Military Skills

OUTCOME MEASURES/ FUNCTIONAL INDEX MEASURES

Gait Lab Analysis with Prosthesis
AMPPRO/AMPnoPRO
Timed Up and Go
6 Minute Walk Test (distances marked on veranda)
Transversus Abdominis Measurements
Sensory Organization Test (NeuroCom Balancemaster)
Oswestry Disability Index (ODI) for low back pain related disability
WRAMC Blast Injury Questionnaire (for blast related sequallae)

No sports until goals are met

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AMPUTEE REHABILITATION ADDENDUM
BILATERAL TRANSFEMORAL PROTOCOL

Revised May 2007

Days 1–5 on Short Prostheses

Goals:
1. Independently don/doff liners and short prostheses & liners
2. Independently roll prone/supine and transition to long sitting
3. Independently transfer in and out of wheelchair wearing prostheses
4. Independently transfer down to and up from 15 inch bench and/or bolster
5. Transfer to and from floor with stand by assist (SBA)
6. Stand in parallel bars on prosthesis x 30 minutes with no skin break down
7. Stand in parallel bars and perform tennis ball circles x 60 seconds each leg
8. Independently ambulate in parallel bars x 50 feet
9. Step up and off 3 inch step in parallel bars forward and laterally x 30 repetitions
10. Ambulate in clinic with 2 canes x 160 feet with contact guard assist (CGA)
11. Ambulate backward and laterally with 2 canes x 30 feet with CGA

Activities:
1. Don/doff liners and prostheses
2. Bed mobility/Transfers with wheelchair, bolster, to/from floor
3. Standing in parallel bars (add tennis ball circles, trunk rotation with medicine ball)
4. Ambulation in/out of parallel bars forward/backward
5. Stepping up/down from 3 inch step
6. Ensure aggressive HF stretching to allow full extension at bilateral hips
7. Patient education on importance of neutral pelvis, flat back and the role of postural alignment in functional bilateral gait

Days 5 – 15 on Short Prostheses

Gait/Stairs Goals:
1. Take prostheses home to increase wear time and tolerance to 4 hours per day
2. Ambulate with one cane x 30 feet
3. Ambulate forward with 2 canes x 600 feet with supervision s. restbreak
4. Ambulate backward and laterally with 2 canes x 50 feet with CGA and theraband around legs
5. Ambulate with one cane x 400 feet and CGA
6. Step up and off 6 inch step in parallel bars forward and laterally
7. Ascend and descent 4 steps using hands and railings with CGA

Balance/Strength Goals:
1. Perform standing chopping movements with weighted ball in parallel bars
2. Standing throw and catch weighted ball in parallel bars with supervision
3. Standing throws with weighted ball against rebounder
4. Stand on 2 dynadisks in parallel bars 1-2 minutes x 4 repetitions
5. Standing 4 way open kinetic chain hip exercises with theraband in parallel bars (can hold bars with one hand)
6. Standing upper body ergometer in prostheses x 10 minutes
7. Standing cone reaching/cone lifting in semicircle
8. Standing chest and arm exercises with universal cable pulley weights
9. Perform supine bicycle core strengthening exercise 3 x 60 seconds in prostheses
10. Perform Pelvic Girdle PNF patterns to facilitate pelvic rotation in semi-supine

Activities:

1. Increase wear time of prostheses
2. Ambulation progression (see goals)
3. Stepping progression (see goals)
4. Standing balance (see goals)

Days 16-30: Raise pylon length/Add microprocessor knee if 8-10 inches clearance

Goals (reset from days 5-15 at increased height):

1. Tolerate wear of prostheses 4-6 hours per day
2. Independently ambulate with one cane x 1000 feet without rest break
3. Independently ambulate with one cane x 100 feet holding weighted ball
4. Perform weighted ball throws against rebounder standing on one dynadisk (progress to one under each foot)
5. Independently ambulate without assistive device x 50 feet

Activities:

1. Increase wear of prostheses to 4–6 hours per day (use for daily functional activities, eg, going to dining hall)
2. Ambulation progression (see goals)
3. Standing balance (see goals)

Days 31-40: Progress to bilateral microprocessor knee prostheses with one microprocessor knee locked in extension

Goals (reset from days 5-30 at increased height):

1. Stair-climbing using one microprocessor knee prosthesis to ride down step with CGA
2. Use microprocessor knee correctly (hit toe load) 95% of time during ambulation

Activities: Ambulation/balance/functional activity progression (see goals)

Note: Only after meeting all above goals will patient be progressed to bilateral fully programmed and functioning prostheses with microprocessor knee.

Days 41+: Progress to bilateral microprocessor knees prostheses with one microprocessor knee in second mode for free swing as tolerated

1. Aggressively pursue heel strikes, single leg step ups, terminal knee extension drills to develop quick contractile hamstring and gluteus maximus musculature.
2. Pursue return to running drills with one mechanical knee and one pylon when able to perform single leg step up to a 14" step x 10 repetitions or 20 unilateral LE repetitions on the total gym on level 10 with each lower extremity.

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