Use of Spinal Orthoses in Rehabilitation

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- Acknowledgements to Dr. Deborah Crane who developed this lecture and slide series.

Objectives

- Recognize common classes of orthoses
- Rank orthoses by amount of immobilization produced
- Identify factors to consider when choosing an orthosis

Outline

- General principles and considerations in choosing an orthosis
- Orthoses for cervical spine
- Orthoses for thoracolumbosacral spine

Considerations in Orthosis Selection

- DEGREE OF DESIRED IMMOBILIZATION
  - Consequences of inadequate immobilization?
  - Compliance?

Other Considerations in Selection

- Weight
- Adjustability
- Functional Use
- Comfort
- Cosmesis
- Cost
- Durability
- Material
- Ease of donning/doffing
- Access to trach, PEG, etc.
- Access to surgical sites
- Provision of aeration

Indications for Spinal Orthoses

- Pain relief
- Mechanical unloading
- Scoliosis management
- Spinal immobilization after surgery or traumatic injury
- Compression fracture management
- Kinesthetic reminder to avoid certain movements

Avoid Unnecessarily Restrictive Orthoses

- Functional
  - Chin control for power wheelchair
  - Balance
  - Ability to look down for self cath or ambulation
  - Swallowing
- Somatic
  - Discomfort (usually increases with restriction)
  - Skin breakdown
  - Loss of ROM

Factors Affecting Immobilization

- Fit of orthosis
  - More restriction with close fit (and with straps tightened fully)
- Body habitus
  - Generally more difficult to immobilize obese patients

Cervical Orthoses

Common Uses of Cervical Orthoses

- Unstable spine
  - Promote bony fusion by restricting motion
  - Prevent further neurologic loss
  - Correct deformity and maintain alignment
  - Prevent progressive deformity
- Neck Pain
  - Acute Neck Pain
  - Chronic Neck Pain
    - Traction: modality or orthosis
- Head Support
  - Severe neck weakness

Biomechanics: Cervical Spine

- C-spine is the most mobile spinal segment
  - C1-2 accounts for 50% of rotation in the cervical spine
  - C5-6 has the greatest amount of flexion and extension
- C-spine is difficult to immobilize
  - Large ROM in multiple planes (coupling)
  - Multiple joints
  - Areas where pressure is hard to apply

Types of Orthoses

Classification based on levels immobilized

- Cervical
- Occipital/Mandibular-Cervical-High Thoracic
- O/M-Cervical-Low Thoracic
- Cranial-Cervical-Thoracic

Soft Cervical Collar

- Class: cervical
- Design: foam, stockinette, Velcro
- Immobilization: very minimal

Soft Cervical Collar

Indications

- Kinesthetic reminder to limit movement
- Warmth
- Psychological benefit? (or harm)

O/M-Cervical-High Thoracic

- Philadelphia collar
- Miami-J collar, Aspen collar, etc.
- Primarily limit flexion-extension
- Better upper cervical restriction than some low thoracic braces

Philadelphia Collar

- Plastizote
- Plastic support struts
- Molded mandibular and occipital supports
- Extends to upper thorax
- Anterior hole for trach available

Philadelphia Collar and Pressure Ulcers

- ~ 1/3 of major trauma patients develop ulcers under collar (usually occipital) after 3 days
- One study shows reduced risk with use of different collar (Aspen)

Philadelphia Collar

- Minimal control of rotation and lateral bending with collar alone

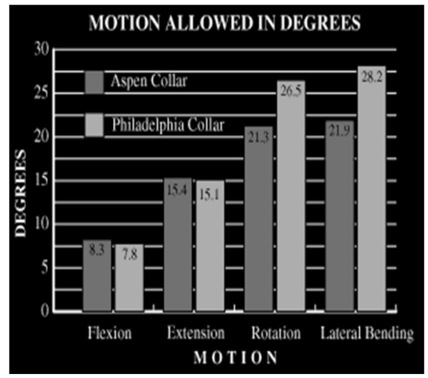
- Philadelphia Stabilizer
  - Lower thoracic extender
  - Aimed at C6-T2 injuries

Miami-J Collar

- Hard plastic
- Cloth pads
- Cutout for trach
- Similar or slightly greater restriction than Philadelphia and Aspen

Aspen Collar

- Similar to Miami-J and Philadelphia
- Slightly better than Philadelphia for rotation and lateral bending



Aspen Vista

- One size fits most adults
- Collar height adjusts with dial

Aspen CTO

O/M-Cervical-Low Thoracic

- 4-Poster Brace
- SOMI
- Minerva Brace

4-Poster Brace

- Anterior and posterior chest pads connected by leather straps
- Molded mandibular and occipital supports
- Less upper C-spine immobilization than others in this class
  - Controls flexion and extension
  - Lateral flexion and rotation not well controlled

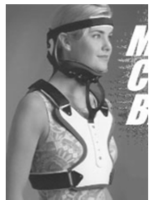
SOMI
(Sterno-Occiptal Mandibular Immobilizer)

- Rigid plastic anterior chest piece connects to occipital plate by uprights
- Removable mandibular piece allows for eating, washing, shaving etc while supine
- No posterior rods; can be donned while supine

SOMI

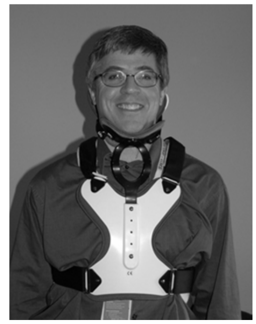
- Controls flexion better than extension
  - Very effectively controls flexion at AO and C1-3 segments
  - Indicated for AO instability caused by RA

Minerva Brace



- Posterior chest plate; optional headband
- Similar to Yale orthosis
- Other “Minerva” braces are different
  - Minerva body jacket
  - Minerva cast

Minerva Brace

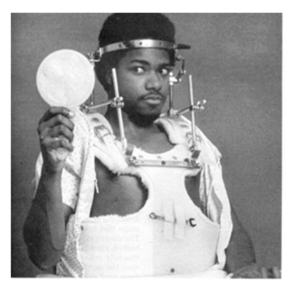


Halo Vest

- Cranial-cervico-thoracic
- External cranial fixation pins secure rigid halo
- 4 posters attach to anterior/posterior vest
- Maximal ROM restriction
  - Used for unstable fx

Halo Vest

Contraindications
- Stable fx when less invasive management could be used
- Concomitant skull fx
- Soft tissue trauma over pin insertion sites

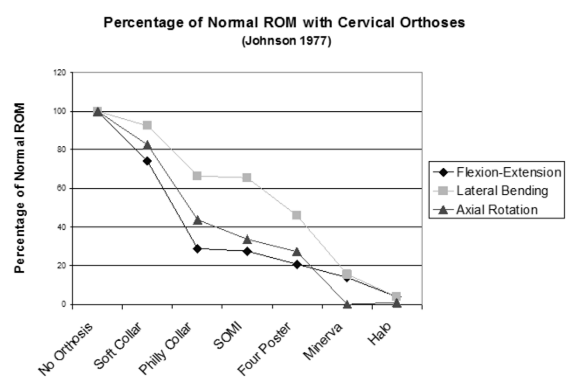


Halo Vest Complications

- Pin-related complications
  - Loosening, infections, scarring
- Vest-related complications
  - Pressure ulcers
- CPR: okay with current designs
  - Read instructions on vest before code

Wire/Bendable Collars

- For patients who will use collar for long-term due to neck muscle weakness
- Adjustable
- Good airflow
- Large open area for tracheostomy
- Example: Headmaster collar



ROM Restriction from Cervical Orthoses

- Order (least→most restrictive) is similar in most studies
- Absolute degrees allowed by each orthosis differs greatly between studies
- Flexion/extension easier to control
- Minimal differences Philly → SOMI
- Halo provides considerably more immobilization in nearly all studies

Orthoses for Acute Neck Pain

Crawford et al, 2004: RCT of whiplash injuries

- Early mobilization with exercise vs. 3 weeks in soft C-collar followed by exercise
- No difference in pain, ROM, ADLs at any follow-up interval
- Those treated with C-collar took significantly longer to return to work after injury

Orthoses for Chronic Neck Pain

- “Not enough scientific testing exists to clearly determine the effectiveness of exercise, traction, acupuncture, heat/cold applications, electrotherapies, *cervical orthoses* and chronic pain / cognitive behavioural rehabilitation strategies”
  - Cochrane Database of Systemic Reviews

Orthosis Selection and Duration of Use after Fracture or Surgery

- Some studies compare orthosis alone vs. surgery plus orthosis
- Almost none compare different collars or duration of use
- Typical duration: 6 weeks – 3 months
  - NO RCTs of post-op bracing

Spinal Orthoses for Thoracic, Lumbar, and Sacral Spine

Biomechanics: Thoracolumbar spine

- Thoracic spine
  - Least mobile spinal segment due to restriction by ribs
  - Primary movement is rotation
- Lumbar spine
  - Primary movement is flexion/extension and lateral flexion
  - Minimal axial rotation due to facet joint orientation

Common Uses of TLSOs

- Acute spinal fracture with paraplegia
  - Immobilize 4 – 5 segments above/below fx
- Immobilization after spinal surgery
- Osteoporotic compression fracture
- Spinal deformity
  - Idiopathic or neuromuscular scoliosis
  - Thoracic kyphosis
- Back pain
  - 2001 systematic review found NO evidence that spinal orthoses are effective in prevention or management of LBP

Degree of Immobilization

- Available orthoses provide varying degree of immobilization (as with cervical spine)
- Fewer studies comparing ROM with TLS orthoses
- Immobilization of upper T-spine can be provided by some of previously described cervical orthoses
  - SOMI, Minerva brace, Halo vest
  - Can add cervical extension to a thoracolumbar brace

Abdominal Binders

- Minimal restriction of movement when used alone
- Compress abdominal contents to limit spinal movement (flexion)

Lumbosacral Corsets

- Plastic or metal stays; uncomfortable if patient moves
- More of a reminder than an immobilizer
- Sometimes used for acute/chronic LBP
- Not appropriate for fracture or post-op use if high degree of immobilization needed



Thoracolumbar Corsets


- Similar to lumbosacral corset, usually with stays across mid to lower thoracic spine
- Limits flex/ex and lateral bending
- Uses
  - Stable spine fractures
  - Post-op immobilization
  - Osteoporotic compression fx

Chairback Brace

- Lumbosacral orthosis
- Posterior and lateral uprights
- Pelvic and low thoracic bands
- Primarily controls flexion-extension of lumbar spine
  - Reduces lateral flexion by about 50%

Jewett Brace

- Hyperextension-type TLSO
- Controls flexion with 3 point pressure
  - Anterior pad on sternum
  - Posterior pad on thoracolumbar spine
  - Anterior pad on pubic symphisis

Jewett Brace

- Limits flexion in lower T- and upper L-spine
- No abdominal compression
- Not appropriate for paraplegia
- Often used with stable compression fractures (T10-L2)

Cruciform Anterior Spinal Hyperextension (CASH) Brace

- Anterior sternal/pubic pads; posterior pad/strap
- Easy to don/doff; difficult to adjust
- Uses:
  - Stable vertebral body fractures
  - Reduce kyphosis in patients with osteoporosis

TLSO Body Jackets

- Prefabricated
  - Example: Boston
  - Generally not appropriate for SCI
- Custom fabrication
  - Usually molded plastic and bi-valved
  - Can be modified after fabrication to adjust fit
- Used for T6-L4 fractures

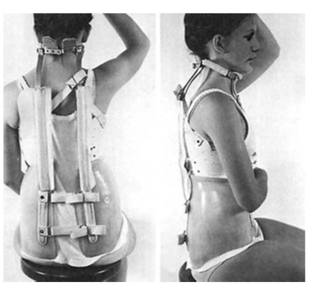
TLSO Body Jackets

- Advantages
  - Forces applied over large surface area
  - Able to limit motions in all directions to high degree
- Disadvantages
  - Risk of skin breakdown if poorly fitting
  - May require new orthosis with weight loss
  - Harder to achieve some functional mobility goals (since it restricts movement so well)

Milwaukee Brace

- CTLSO with lateral pads in non-circumferential arrangement
- Used for treating idiopathic scoliosis in conjunction with other treatments
  - Discomfort from brace components causes patient to actively contract spinal muscles and correct spinal curvature
    - Trunk muscles are in constant use, consequently, disuse atrophy does not occur

Milwaukee Brace



Treatment of Idiopathic Scoliosis

- Bracing usually begins with 25^{o} curve
  - Ineffective in adolescents when >45^{o} curve
- Apex of curve T9 or lower ➔ TLSO
- Apex higher than T9 ➔ Milwaukee Brace
- Strong evidence that bracing prevents curve progression

Treatment of Neuromuscular Scoliosis

- Milwaukee brace is a poor choice
  - Patient lacks voluntary motor control to correct spinal deformity and may have spasticity
  - Pressure distribution isn't as even as with a molded body jacket
- Usually treated with TLSO body jacket

Immobilizing Upper and Lower Ends of TLS Spine

- Upper Thoracic Spine
  - Cervical extension frequently recommended (CTLSO)
- Lower Lumbar Spine
  - TLSOs can increase movement at LS junction
  - To immobilize lowest part of L-spine, one thigh must be immobilized in extension

Cost of Orthoses*

- Soft: $50
- Philly: $125
- Miami J: $150
- Aspen: $160
- SOMI: $480
- Halo: $2800
- Headmaster: $105
- Jewett: $460
- Knight-Taylor: $540
- Milwaukee: $2200
- Custom TLSO: $1500

* (per eMedicine reference)

What is the primary stabilizing effect of the flexible lumbosacral orthosis (AKA abdominal binder)?

1. Restricting spinal extension
2. Preventing atrophy of trunk muscles
3. Elevating intra-abdominal pressure
4. Enhancing kinesthetic feedback

What is the primary advantage of a sterno-occipital-mandibular immobilizer orthosis (SOMI)?

1. The SOMI limits cervical extension exceptionally well.
2. The SOMI is easy to don while the patient is supine.
3. The SOMI offers a high level of patient comfort.
4. The SOMI limits atlantoaxial motion exceptionally well.

Which spinal orthosis is used to prevent thoracic spinal flexion by providing 3-point pressure over the sternum and pubis anteriorly and the upper lumbar spine posteriorly?

1. (a) Custom molded, plastic thoracolumbosacral orthosis
2. (b) Lumbosacral corset with posterior metal stays
3. (c) Jewett orthosis
4. (d) Taylor orthosis

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REVIEW OF NORMAL AND PATHOLOGIC GAIT
Mark Guthrie, PT, PhD
March 16, 2015

OBJECTIVES:

After listening to this presentation and studying the accompanying syllabus material, attendees will be able to:

1. Describe the breakdown of the gait cycle into swing vs. stance, and know the periods of single and double support.

2. Name the RLA (Rancho Los Amigos) phases of gait and their proportions of the cycle.

3. Define stride duration, swing duration, stance duration, stride length, step length, base of support width, cadence, and velocity, including the approximate normative values of each.

4. Describe the gross kinematics at the hip, knee, and ankle during normal gait

5. Describe the major muscle acitivity during each RLA phase of gait.

6. Describe common orthopaedic gait deviations, including typical compensation that result.

Overview of Biomechanics

Of all human movements, walking has by far received the most study. What we learn from biomechanical analyses of walking provides a framework for studying all kinds of movements, such as reaching and grasping, sucking, mastication and swallowing, and movements of the eyes. Even for those clinicians who will not directly treat gait deviations, an understanding of gait biomechanics and a familiarity with normal gait will provide a quick window into the patient's level of function because gait is such a common and readily observable activity that involves so much of the body.

Temporal and Spatial Measures

Temporal and spatial measures examine global aspects of gait. Because gait is a cyclical activity, the basic assumption is that one step is essentially the same as the next. Thus, a parameter such as stride length is expected to be characteristic of the person's overall walking performance, not just the step(s) measured. The following list includes typical values for the common measures:

Stride: The period from contact on one extremity until the next contact on that extremity. One stride is one "cycle" of gait. A step is the period from contact on one extremity until contact on the opposite extremity

Stride Duration (cycle duration, cycle period): Males 1.1 sec/stride; Females 1.03 sec/stride

Stance Time (stance duration): 60% of one cycle of gait

Swing Time (swing duration): 40% of one cycle of gait

Single Support Time: 80% of one cycle

Double Support Time: 20% of one cycle

Stride Length: Male 1.5 meter; Female 1.3 meter

Step Length: half of stride

Base of Support Width: 2-12 cm between heels

Degree of Toe Out: ~ 7 degrees

Cadence (step rate): Male 110 step/min; Femaile 116 step/min

Velocity: Typical = 80 m/min; Male 80-91; Female 73-81

Phases of Gait

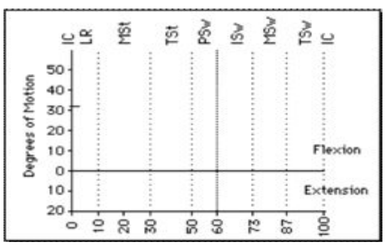
Gait, particularly walking, is a cyclic phenomenon that can be divided into segments, or phases. Two sets of terminology are currently in use: the *traditional terminology* and the *Rancho Los Amigos* (RLA) system. The traditional terminology developed as interest in gait rehabilitation mounted after WWII in the effort to improve lower extremity prosthetics. It describes gait in terms of discreet, momentary events, such as heelstrike, heel rise, and toe-off. The RLA terminology became increasingly popular in the late 1980's and early 1990's and is currently assuming a position as the preferred standard among clinicians. It describes gait more in terms of processes or segments of time, such as loading response, terminal stance, and pre-swing, and because it is semantically more generic and better encompasses the common features of normal and pathological gait. T traditional terminology uses the term "heel strike" where the RLA system uses the term "initial contact" to refer to the instant when the limb contacts the ground. "Initial contact" applies equally well to the gait of a child with cerebral palsy who actually makes contact with the toes as it does to the gait of a person with an amputated lower extremity or a person without disability who makes contact with the "heel". In communicating with your colleagues and to understand the published literature, however, you will need to be fluent in both nomenclatures.

While the phases of gait defined in the RLA terminology are fine for walking, which is usually the focus of medical rehabilitation, additional nomenclature applies when studying running, which may be important in a sports-related, orthopedic practice. For both walking and running, stance gets much shorter and swing gets slightly shorter as speed increases. Thus, as speed increases, the *proportion* of the cycle devoted to stance decreases and the proportion of the cycle devoted to swing increases. For very fast sprinting, the absolute duration of swing may actually begin to increase as extremely high speeds are reached.

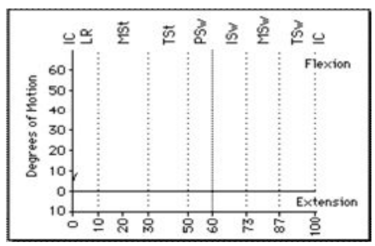
The following several pages provide graphic and written descriptions of the most important events and phenomena for each RLA phase of normal gait.

Initial Contact

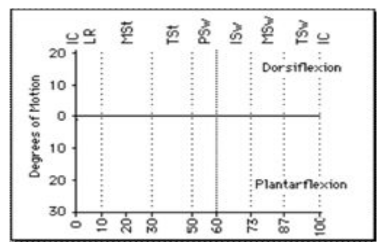
You will want to know the material on this and the following pages so well that you can recite it in your sleep, backwards.



HIP POSITION

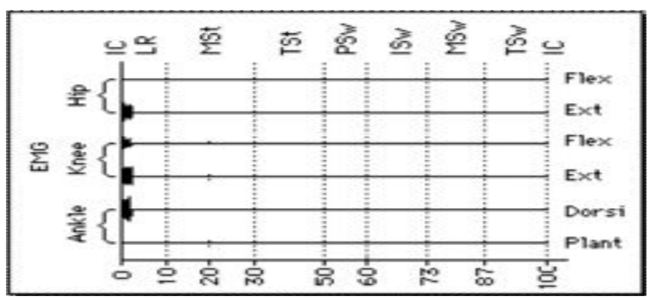


KNEE POSITION



ANKLE POSITION

GROSS MUSCLE ACTIVITY



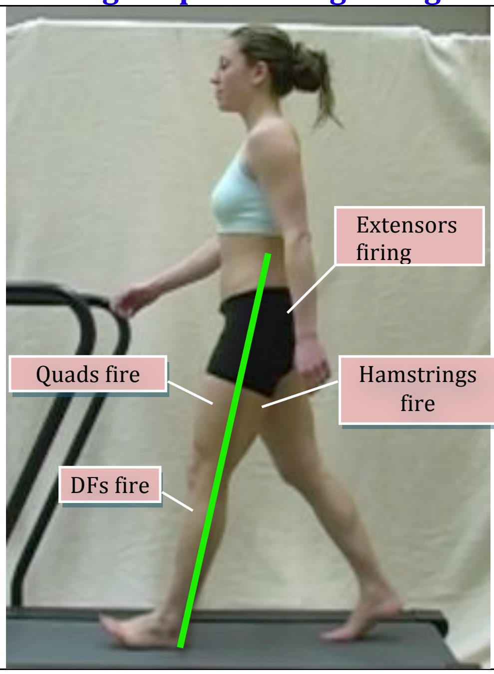
Initial Contact = Not really a phase of gait, but rather the instant when the foot hits the ground. Ideally, first contact is with the heel so that the limb is positioned to begin stance with a heel rocker. This is the beginning of DOUBLE LIMB SUPPORT. The position of the GRF vector at Initial Contact is sometimes misleading, so I have not displayed it above.
Muscle activity is in transition from Terminal Stance to Loading Response = preparation for weight acceptance.

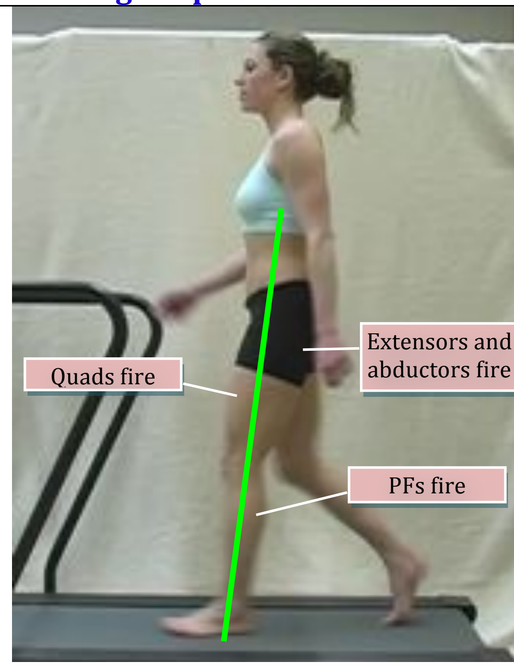
Hip at ~30° flexion. Hip extensor activity.

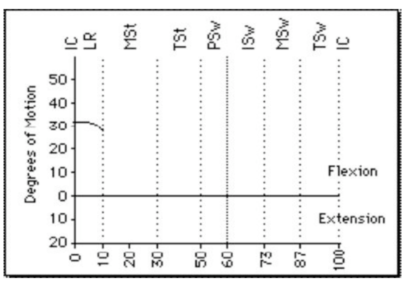
Knee: ~5° flexion. Quad and hamstring activity, for stability.

Ankle: neutral. Dorsiflexor activity has been keeping the foot from plantarflexing and is now going to resist the plantarflexion moment of loading response (when initial contact is at the heel).

Loading Response - Beginning	Loading Response - End







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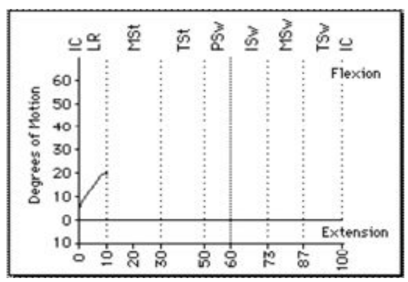

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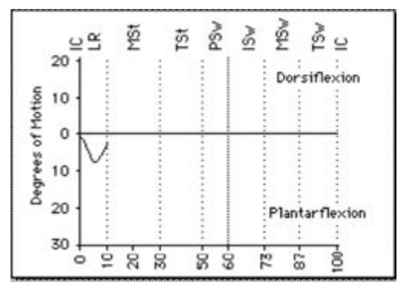
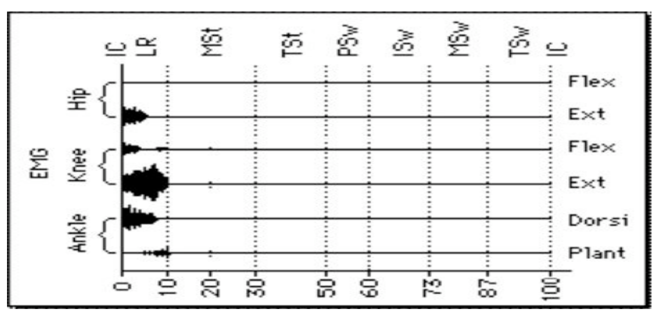


ANKLE MOTION

GROSS MUSCLE ACTIVITY



Loading Response begins w/ IC and continues until the other foot is lifted for swing. Shock is absorbed as weight is transferred to the outstretched limb.

- 0-10% of gait cycle
- Basically the opposite of Pre Swing
- The initial double stance period
- A critical phase (weight acceptance, lots of torque, potential for instability)
- Heel Rocker action
- External PF torque initially
- Critical events: Hip stability, controlled knee flexion and PF, pronation

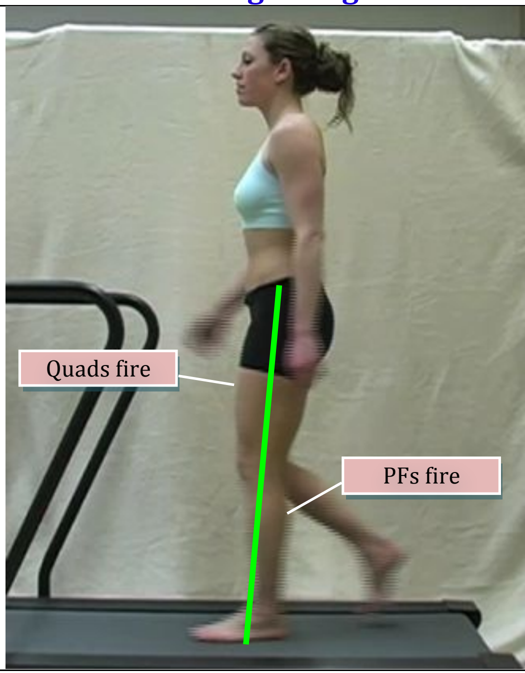
Hip: From ~30° flexion may extend slightly. GRFV in front of hip = flexion torque, thus extensor activity

Knee: Begins at ~5° flexion (ideal for absorbing "shock"); ends ~20 flex (nearly its peak flexion). Motion: ~15° flex
GRFV moves posterior to knee (=external flexion torque, thus the internal extension torque)

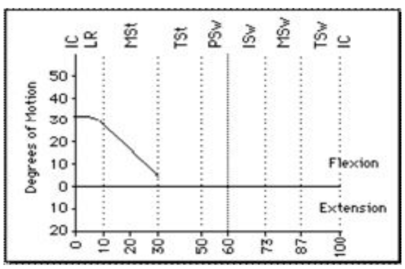
Ankle: Begins at neutral with heel contact; this initiates a heel rocker and creates PF moment which is resisted by DF mms; once "footflat" is achieved PF ceases and DF begins, causing the plantarflexors to begin firing.
Motion: 8° PF until "footflat," then 8° DF as tibia rocks forward.
Ankle is pronating* (eversion torque; TA and TP active)

* IR of tibia induces pronation

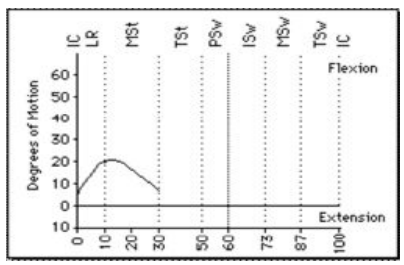
MIDSTANCE - Beginning



MIDSTANCE - End



HIP MOTION



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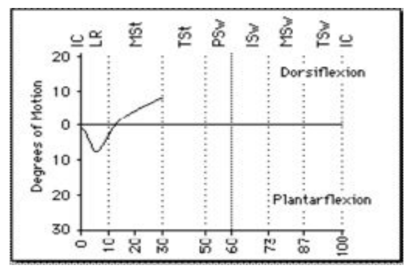
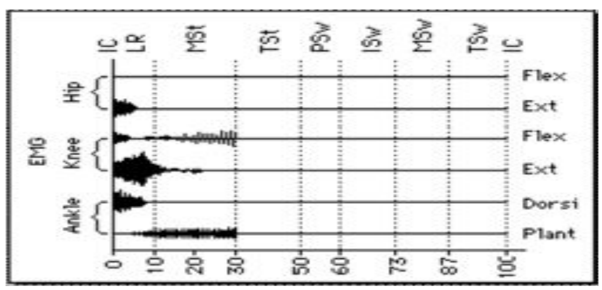


ANKLE MOTION

GROSS MUSCLE ACTIVITY



MIDSTANCE

-Interval = 10-30% of gait cycle

-It's the beginning of single support.
-Starts as the other foot is lifted from the ground and continues until the body weight is aligned over the forefoot (and tibia of swing leg approaches vertical).
- Ends with heelrise
- A period of relative control, when your momentum moves your mass forward and slightly up (to the top of the pendulum) and great muscle activity is not usually required.

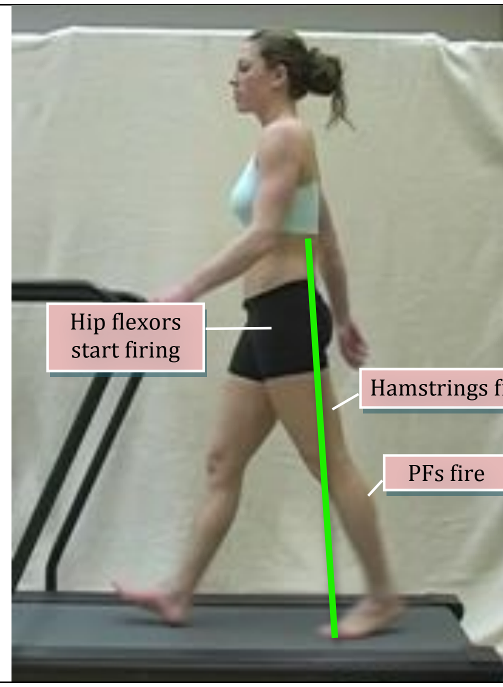
Hip: steadily extends toward neutral, achieving ~5° flexion Motion= ~25° of extension. Abductor (frontal plane) mm activity! Otherwise minimal mm activity. GRFV near hip.

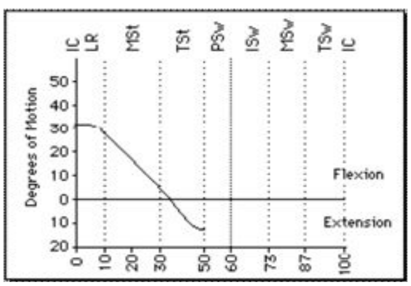
Knee: Flexion ceases early at ~20°, thereafter knee extends to ~8°. Thus motion= ~12° extension.
May be some hamstring activity early, but mostly extensor (quad) activity – this diminishes as GRFV passes thru, then anterior to the joint.

Ankle: Steadily dorsiflexes to ~10°. This is the ankle rocker which allows progression over the weightbearing limb.
-Motion: ~10° DF. Eccentric gastroc and soleus activity, acting to resist (slow down) DF.
Ideally, pronation slows & ceases early, followed by re-supination (and ER of the leg).

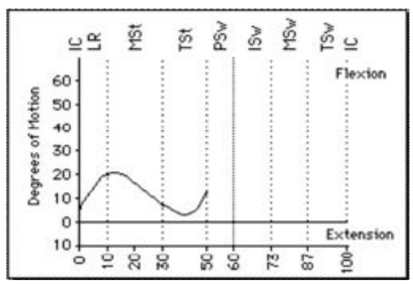
TERMINAL STANCE - Beginning

TERMINAL STANCE - End

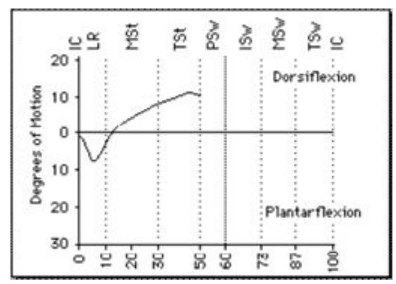




HIP MOTION

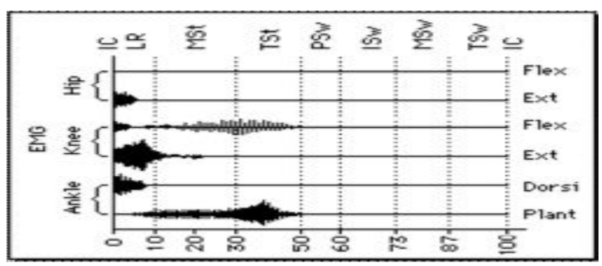


KNEE MOTION



ANKLE MOTION

GROSS MUSCLE ACTIVITY



Terminal Stance completes the period of single support. Begins with heelrise and ends when the opposite foot strikes the ground. In this phase the body moves ahead of the forefoot

30-50% of the gait cycle
High vertical forces with the initiation of "push-off" result in greater torque demands.
-Critical events: Heelrise: In spite of this the ankle is initially still dorsiflexing; DF slows then stops (due to gastroc/soleus activity), followed by PF; ↑gastroc/soleus activity; foot should be re-supinated and stable; Toe-rocker

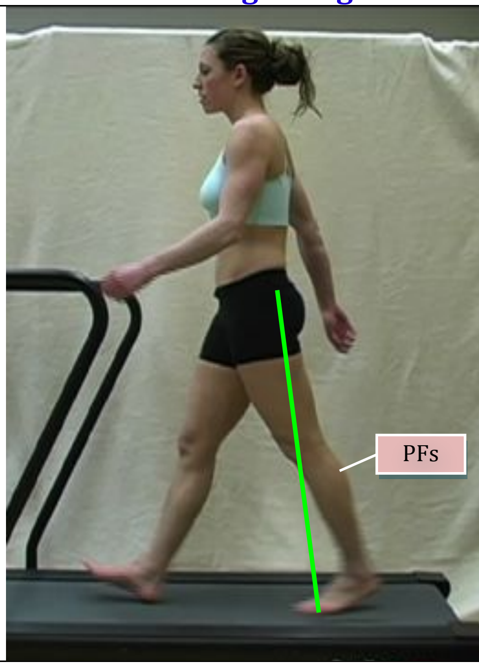
Hip: Continued extension thru neutral to ~10° extension, for a total arc of ~15°. GRFV moves posterior to the joint, creating an extension moment. This is going to stimulate flexor activity eventually.

Knee: Continues extending to ~5° flexion, then reverses and flexes to ~12°; Motion during TSt: ~3° ext, ~7° flex. Little mm activity (possibly flexor). GRFV moves close to knee

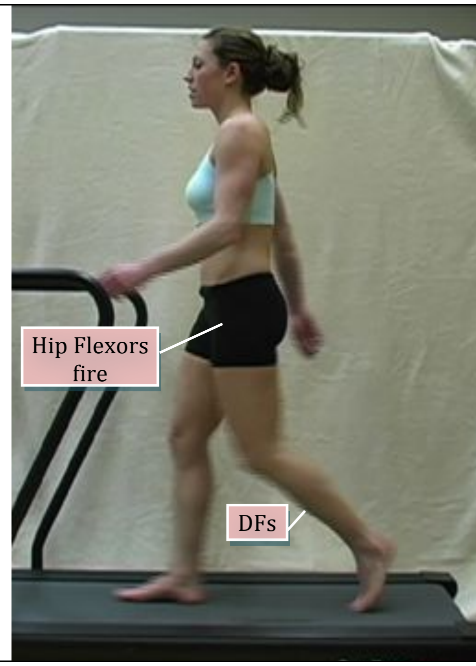
Ankle: DF to a peak of ~12° DF, reversing near the end of the phase to reach ~10° DF. Motion: 2° DF, 2° PF

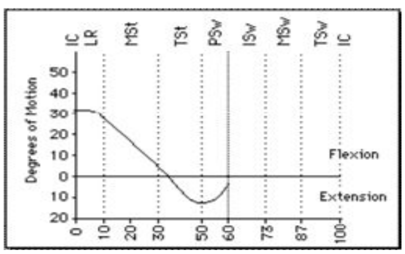
GRFV moves anterior to metatarsal heads. Eccentric, then isometric, then concentric PF activity: gastroc, soleus,TP, FDL, FHL – the whole enchilada!

PRE-SWING - Beginning

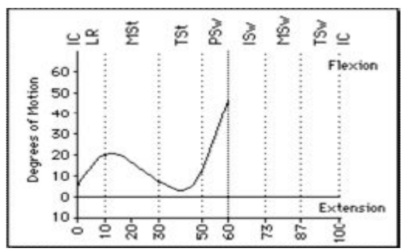


PRESWING - End

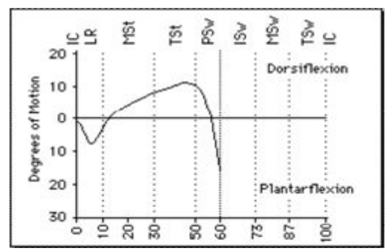




HIP MOTION

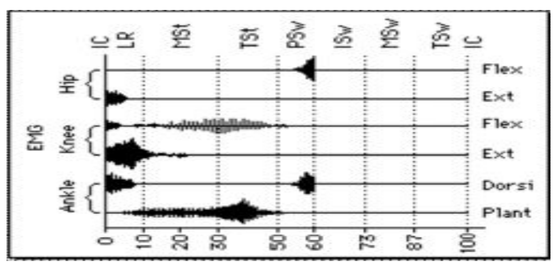


KNEE MOTION



ANKLE MOTION

GROSS MUSCLE ACTIVITY



Pre-Swing is the final phase of stance, and the 2nd period of double support. Begins with initial contact on the opposite side and ends with ipsilateral toe-off. Rapid unloading of the limb occurs as weight is transferred to the opposite side. Sometimes called "weight release" or "weight transfer" phase (I like Unloading Response).

Interval = 50-60% of gait cycle.

A major objective of Pre-Swing is to position the limb for swing.
Passive knee flexion to ~40° and lots of PF

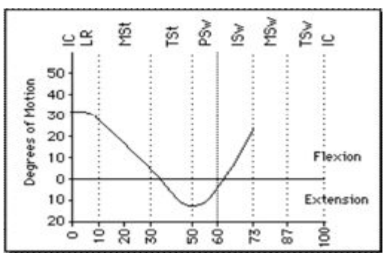
Hip: Reversal of direction, so that flexion to nearly neutral (0°) occurs. Motion= 10° flexion. Concentric hip flexor activity, a very important part of propulsion.

Knee: Rapid flexion to ~40° for an arc of 28°. Some rectus femoris & sartorius activity.

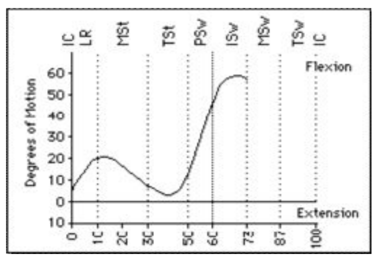
Ankle: Rapid PF from 10° DF to ~20° PF. Continued gastroc/soleus activity initially, but this drops off as weight is released and shifted onto the other limb.
Motion: 30° PF

INITIAL SWING - Beginning

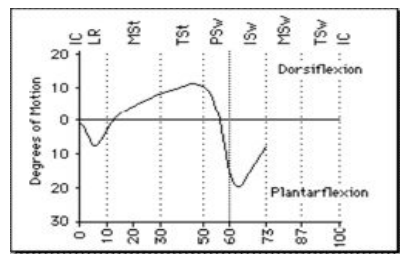
INITIAL SWING - End



HIP MOTION

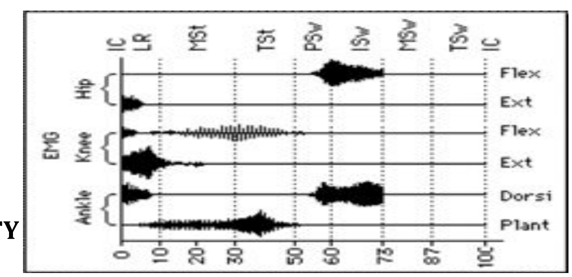


KNEE MOTION



ANKLE MOTION

GROSS MUSCLE ACTIVITY



Initial Swing is the first third of swing period. Begins with lift of the foot from the floor and ends when the swinging foot is opposite the stance foot.

Interval= 60-73% of gait cycle

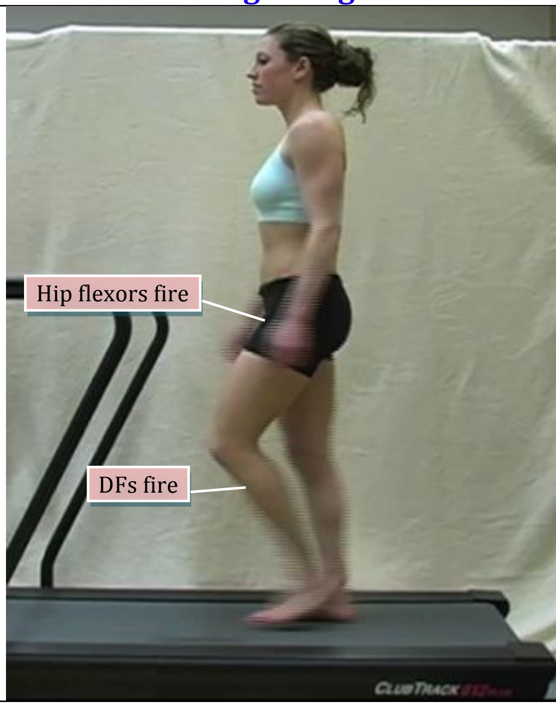
Two important objectives are advancement of the limb from its trailing position and clearance of the swinging foot.

Hip: Rapid flexion from neutral to ~25° flexion, thus an arc of 25°. Hip flexor activity (this is Swing Phase folks!).

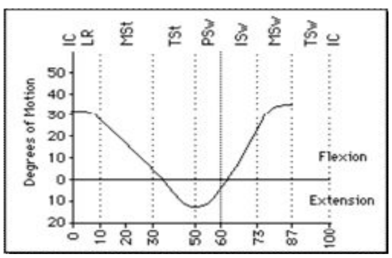
Knee: Continues flexing during most of this phase, reaching a peak of ~60°. Then motion reverses so that at the end of the phase a position of ~55 of flexion is achieved.
Motion: ~20° flex, then 5° extension.
Little mm activity (possibly some biceps femoris).

Ankle: A tiny bit of plantarflexion initially, but then dorsiflexion to about 10° in order to clear the toes.
Motion: 3° PF, 10-12° DF
Dorsiflexors are active.

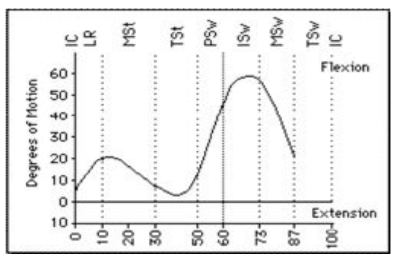
MID-SWING - Beginning



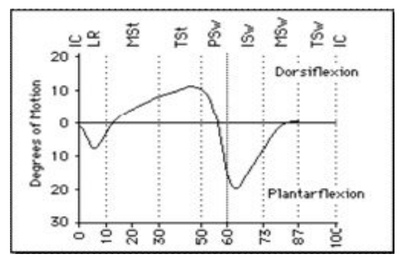
MID-SWING - End



HIP MOTION

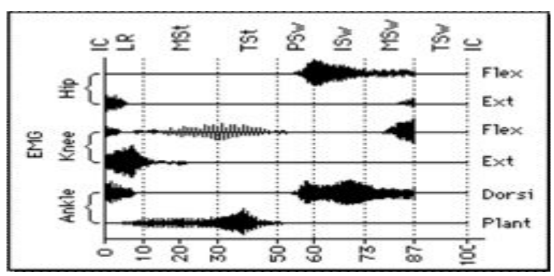


KNEE MOTION



ANKLE MOTION

GROSS MUSCLE ACTIVITY



Mid Swing begins when the swinging foot is opposite the stance foot and ends when the swining limb is forward and tibia vertical (hip and knee flexion postures are approximately equal).

Interval=73-87% of gait cycle

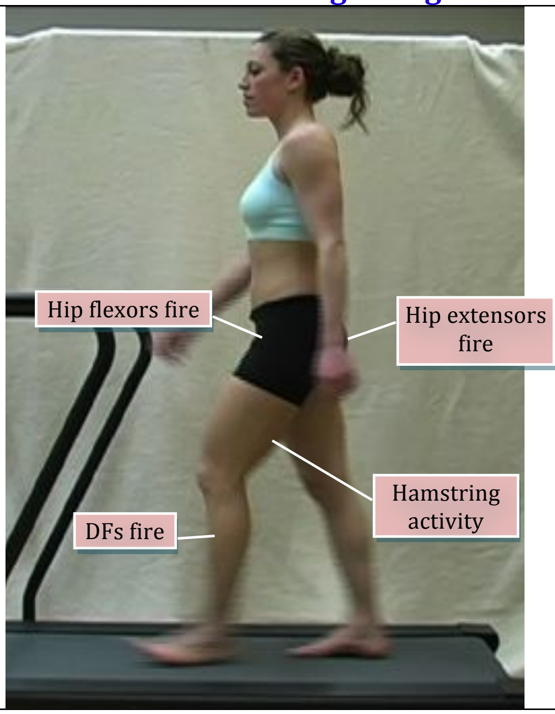
Advancement of the swinging limb and clearance of the foot continue to be important objectives. Like Midstance, this is a period of relative control (you're sort of letting things happen.

Hip: Flexion slows, then stops at the end of the phase, at a position of ~35° (of flexion). Motion = 10° of flexion. Flexor activity initially, then extensors kick in (hamstrings mostly) to slow down the swinging limb.

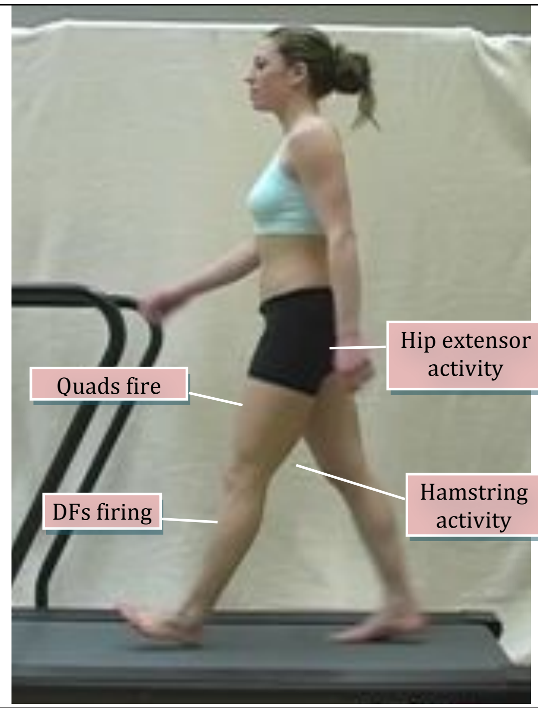
Knee: Rapid extension to a position of ~20° flexion. Motion: ~35° of extension. A little hamstring activity toward the end of the phase, to keep the knee extension under control.

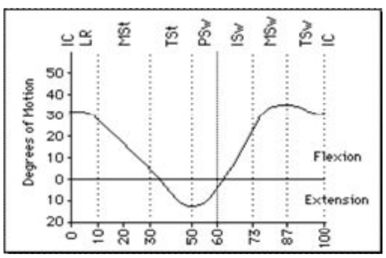
Ankle: Dorsiflexion to neutral early on. Motion ~10° DF. Dorsiflexors continue to be mildly active to maintain the position of the ankle.

TERMINAL SWING - Beginning

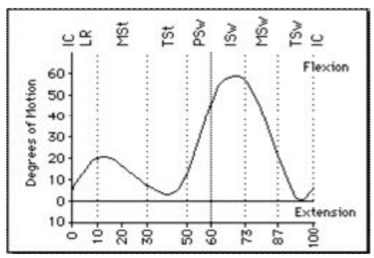


TERMINAL SWING - End

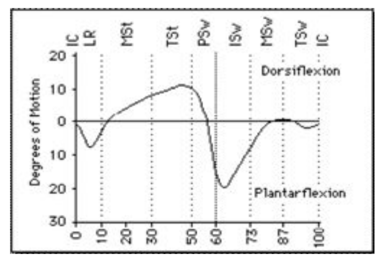




HIP MOTION

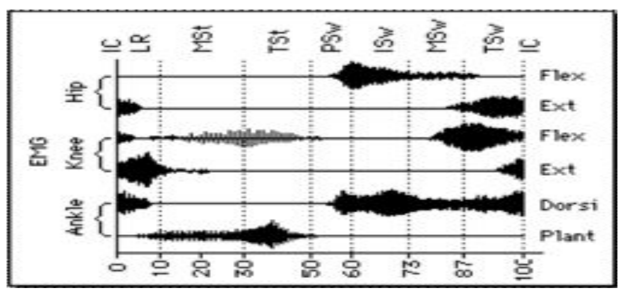


KNEE MOTION



ANKLE MOTION

GROSS MUSCLE ACTIVITY



Terminal Swing: the final third of the swing period. Begins with a vertical tibia and ends when the foot strikes the floor/ground. Limb advancement is completed as the leg moves ahead of the thigh. The knee maximally extends.

Interval: 87-100% of gait cycle

Two important objectives are completion of limb advancement (deceleration of the swing limb) and preparation for stance.

Hip: Mostly holds steady, but may extend slightly to a position of ~30° (of flexion). Motion= 0-5° extension. Increasing activity in extensor muscles (decelerating the swinging limb).

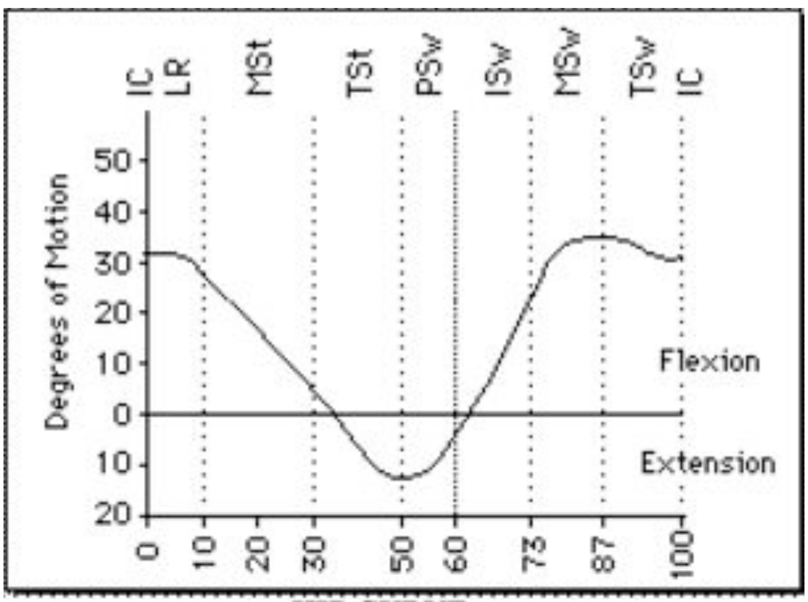
Knee: Continues extending, nearly reaching neutral (0°), then near the end of the phase the knee flexes slightly to ~5° flexion (better for shock absorption).
Motion: ~20° extension, 5° flexion.
Initially mostly flexor activity, then extensors (quads) as well, for stability & in preparation for loading.

Ankle: remains in neutral. Increasing dorsiflexor activity at the end of the phase, which is helpful in preparation for the big plantarflexion moment that is about to occur.

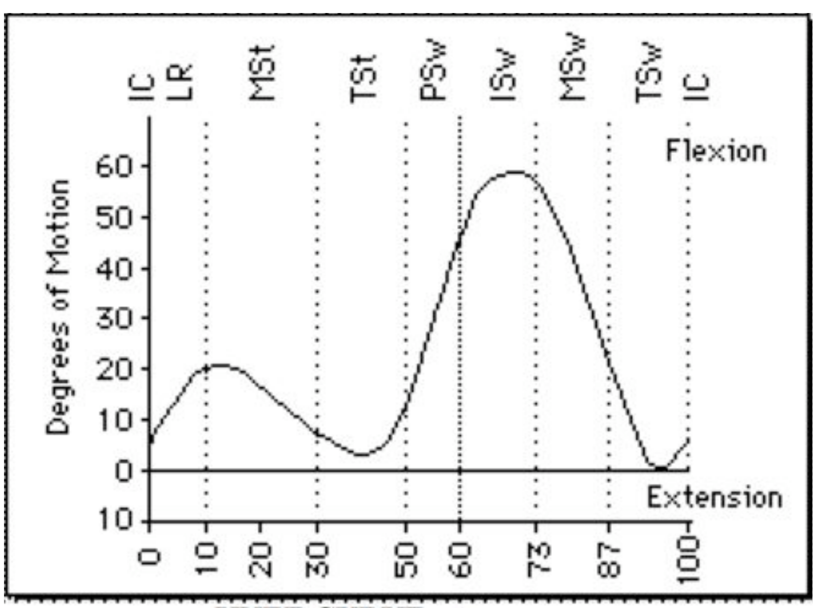
Lower Extremity Kinematics

Sagittal plane motions

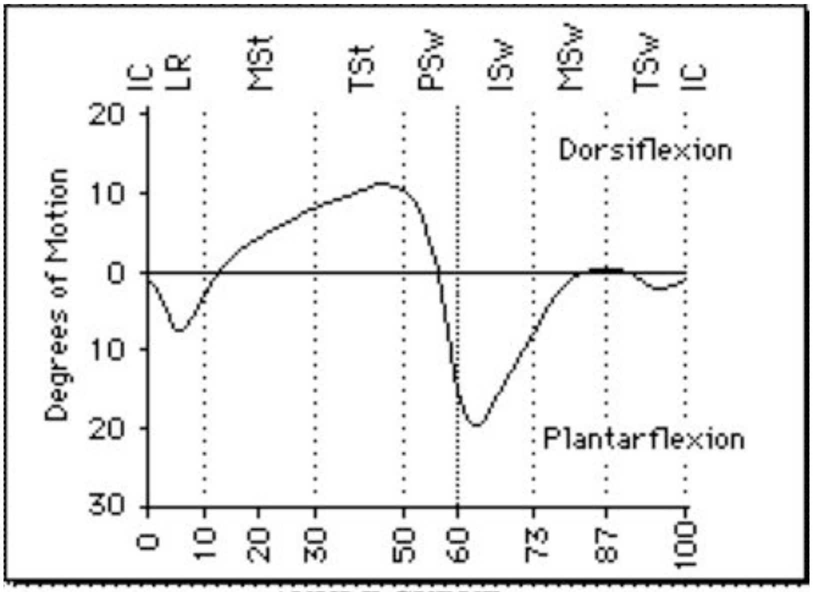
The following plates are graphic representations of the overall sagitall plane motions at the hip, knee, and ankle. It is recommended that you be able to describe such things as the position of each joint at the beginning and end of each phase, motions that are occurring during each phase, and total excursions at each joint during each phase. Hip, knee, and ankle sagitall plane motions and explanations during each phase of gait are shown in the previous section.



HIP CURVE



KNEE CURVE



ANKLE CURVE

Motions in other planes

Pelvic Rotation

The pattern of pelvic rotation is fairly symmetrical. The pelvis rotates externally from initial contact until the onset of preswing, the first 50% of the cycle, and internally during preswing and swing, the second 50% (Note: External pelvic rotation means that if the stance limb were the right, the pelvis would be rotating to the right as seen from above).

Hip Internal and External Rotation

The hip rotates ± 8° from neutral in a monotonic fashion (*i.e.*, like a sine-wave, with one maximum and one minimum). Peak internal rotation occurs during Pre-Swing, and peak external rotation occurs toward the end of Loading Response. That is, rotation at the hip trails pelvic rotation slightly -- so at the end of Loading Response the hip begins internally rotating and continues to do so until well into Pre-Swing when it begins externally rotating (and does so until well into Loading Response).

Hip AB / AD duction

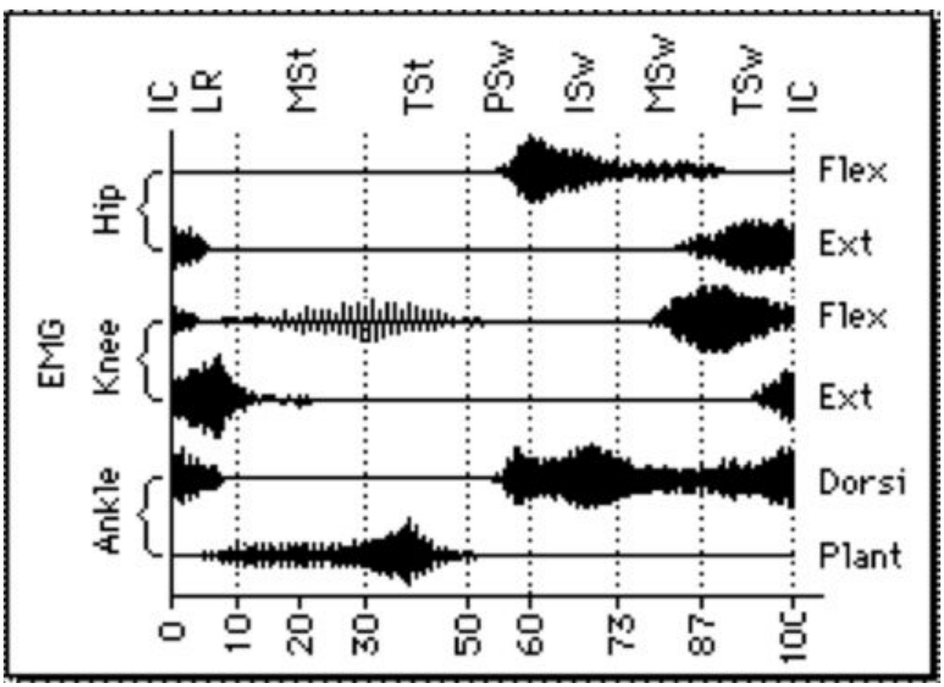
The hip ab- and adducts ± 7° from neutral. During the loading response, the pelvis undergoes a controlled drop on the contralateral side, thus the ipsilateral hip adducts under the eccentric control of gluteus medius and minimus. During midstance, the hip moves in the abductor direction, returning to neutral (level pelvis) by the onset of terminal stance and more or less remaining so until the onset of preswing. Just the opposite occurs thereafter, with rapid abduction as the limb is unloaded during preswing, etc. The "bump, flat, dip, flat" pattern characteristic of self-paced walking changes to a more sinusoidal pattern during rapid walking and running.

SUBTALAR JOINT

The subtalar joints vary ± 5° from neutral in a roughly monotonic fashion. There is rapid eversion during the loading response, which slows greatly but continues into midstance. The subtalar joints begin re-supinating during midstance, ideally returning to neutral during terminal stance. Peak inversion occurs during preswing and the subtalar joints actually begin to return towards neutral before toe off. The return to neutral is completed during initial swing, and the subtalar joints hover near neutral for the remainder of swing, often entering initial contact in slight inversion (thus contact on postero-lateral heel).

Lower Extremity Kinetics

Below is a gross, graphic representation of muscular activity related to the hip, knee, and ankle during gait. Your goal is to understand and be able to describe the the material in the graph from as many perspectives as possible = exactly what muscles are active and when, why they are active, what they are accomplishing, the position of the ground reaction force vector at any given time and its affect on torques at each joint, etc. Descriptions of muscular activity during each phase of gait are found in the first section.



COMMON PATHOLOGIC GAIT ABNORMALITIES

Normal walking is the standard against which pathology is measured. Efficiency is often reduced in pathology

Focal Weakness

Focal weakness of one or more LE muscle groups can be seen in a wide variety of disorders. The rehabilitation of the gait abnormalities due to focal weakness is relatively straightforward and relies primarily on substituting for the biomechanical deficits using bracing and assistive devices (plus strengthening if possible, of course). The more commonly encountered gait abnormalities are described below.

Ankle Dorsiflexor Weakness

COMMON ETIOLOGIES:
Peroneal nerve injury at the fibular head due to trauma or compressive injuries; anterior horn cell disorders; peripheral neuropathy; severe L4 or L5 radiculopathies; myelodysplasia.

"NORMALLY": At foot contact, the dorsiflexors eccentrically contract to assist in limb loading and shock absorption as the foot plantarflexes from heel strike to a foot-flat position.

PATHOLOGICAL PRESENTATION:
With mild to moderate weakness, this motion is poorly controlled (restrained) leading to "foot slap", which is best observed as walking speed increases. Lateral ankle stability may be reduced (remember, the dorsiflexors also evert or invert), increasing the risk of sprains and injuries. When weakness is severe, heelstrike may be absent entirely because of an inability to dorsiflex the foot during swing.

During swing. toe clearance is reduced. This functionally lengthens the swing phase limb. A "steppage gait" (increased hip and knee flexion) is typically adopted to supply the necessary clearance.

Rx: AFO.

Plantar flexor Weakness

COMMON ETILOGIES:
Tibial neuropathy from trauma; peripheral neuropathies (in combination with peroneal weakness); AHC disorders; plexopathies; S1 radiculopathies; myelodysplasia.

"NORMALLY":
During stance. the plantarflexors normally undergo an initial eccentric contraction which controls forward tibial rotation. This is followed by a concentric contraction during pushoff which assists in moving the limb forward into swing.

PATHOLOGICAL PRESENTATION:
When weakness is present, excess anterior sagittal plane tibial rotation (ie, dorsiflexion) is present in mid and late stance(i.e. the foot remains dorsiflexed and heel rise is lost or attenuated). The rapid forward rotation of the tibia in stance moves the knee forward, prolonging the time during which the GRF line passes behind the knee. This increases stance phase knee flexion and the muscular demands on the quadriceps. The beneficial feature of the increase in knee flexion is to slow (but not prevent) trunk advancement over the stance phase leg. As the trunk continues its forward progression over the stance leg, the COM move further forward of the ankle joint, increasing the moment (torque) that is normally countered by the plantarflexors. This leads to a potentially unstable situation requiring than the stance limb be quickly unloaded to prevent dorsiflexion collapse. The contralateral leg step length (swing duration) is reduced so that double support is achieved early.

Rx= AFO

Quadriceps Weakness

COMMON ETIOLOGIES
2° femoral neuropathy from trauma; diabetic amyotrophic / mononeuropathy; AHC disorders; lumbar plexopathies; L3/4 radiculopathies.

"NORMALLY":
At heelstrike, the quads normally eccentrically contract to control limb loading and prevent excessive knee flexion.

PATHOLOGICAL PRESENTATION:
With mild to moderate weakness, the knee is extended at or prior to heelstrike and knee flexion is eliminated or reduced. At times, this movement into full extension can be quire forceful, snapping the knee back. When normal plantarflexor and hip extensor strength is present, knee extension can be maintained by use of the hip extensors acting in a closed kinetic chain and/or by increased plantarflexor activity, which shifts the COP forward on the foot, in turn moving the GRF line in front of the knee.

With more severe weak ness, the likelihood of knee instability and collapse increases. Additional strategies may be adopted to assist in knee control and to ensure that the GRF line always passes in front of the knee. These include forward trunk leaning, development of recurvatum, and use of upper extremities to assist in knee extension.

RX:
With mild to moderate isolated weakness, use of a cane or other UE aid that allows for the shifting of the COM anterior to the knee for increased stability is usually adequate.

When paralysis is complete or when recurvatum develops, bracing may needed, often an AFO with some PF built in.

Hip Abductor Weakness

COMMON ETIOLOGIES:
Usually seen in combination with other proximal weakness from plexopathies, myopathies, AHC disease, myelodysplasia; may result from severe disuse/bed rest; often is a component of UMN gait; hip joint pathology.

"NORMALLY":
During stance, the hip abductors stabilize the pelvis, limiting downward rotation in the frontal plane.

PATHOLOGICAL PRESENTATION:
During midstance, the pelvis drops toward the swing leg and there is visible lateral movement of the hip toward the stance leg. This gait pattern is known as the "uncompensated gluteus medius" or "Trendelenburg" gait and is most common when mild or moderate isolated hip abductor weakness is present. When weakness is more severe or hip pain is present, a common biomechanical compensation is to shift the COM toward the stance leg in order to decrease the stabilizing force required by the hip abductor. This compensated gait appears as a lateral shift and bending of the trunk over the stance-phase leg. Faster walking may mask the problem by reducing the time during which gravity can operate.

RX:
Assistive devices used in contralateral hand allow development of a torque opposing the pelvic drop.

Hip Extensor Weakness

COMMON ETIOLOGIES:
With trauma to gluteal nerves, may see in isolation; more often seen in combination with other proximal weakness from plexopathies, myopathies, AHC disease, myelodysplasia.

"NORMALLY": At heelstrike and in stance, the forward motion of the leg is slowed. Because of inertia, the trunk will tend to continue forward. The hip and back extensor muscles contract to control forward rotation of the trunk about the hip (pitch). In addition, hip extensors appear to also function in limb loading to assist in control of early knee flexion acting via the closed kinetic chain.

PATHOLOGICAL PRESENTATION:
With weakness, several compensatory patterns are observed. Walking speed is slowed to reduce forward momentum (often early strategy when weakness is bilateral and affects both hip and back extensors). The trunk COM is moved relatively posterior by increasing lumbar extension or posterior trunk lean. This allows the GRF line to pass close to or posterior to the hip, allowing gravity to assist in maintaining joint stability.

When weakness is bilateral or associated with limited hip extension, as is common in generalized myopathies, the increase in lordosis is often typically present. When weakness is isolated t gluteus maximus, there is a backward thrust or throwing of the trunk at heelstrike, which moves the trunk posteriorly. To reduce any tendency for the hip to move into flexion, there is a reduction in knee flexion and the limb is maintained in a more extended position.

RX: 1° intervention with proximal weakness is strengthening when appropriate and the use of UE assistive devices to ensure trunk stability.

Hip Flexion Contracture

COMMON ETIOLOGIES:
Bed rest; joint disease; CDH; prolonged sitting posture (W/C).

"NORMALLY": During stance, the hip joint normally moves from a position of about 20-30 degrees of flexion at initial contact to 10 degrees of extension in terminal stance as the trunk moves smoothly over the stance limb. Normally, the trunk remains vertically oriented over the stance limb as hip, knee and ankle motion are coordinated to keep the pelvis relatively level.

PATHOLOGICAL PRESENTATION: Hip joint pathology causes limitations primarily of internal rotation and extension through a combination of bony restrictions and soft tissue (anterior joint capsule) contracture.

When a hip flexion contracture is present, abnormalities will initially be seen during the latter half of stance, when maximal extension range is needed. When extension range is lacking, the pelvis must flex forward. Without any compensatory motion, this would force the trunk into a forward leaning position, moving the GRF anterior to the hip and increasing the hip extensor muscle torque required to stabilize the trunk. The most common compensatory strategy used by patients is to increase lumbar spine extension (i.e., lordosis) to allow the trunk to remain vertically oriented. Lumbar spine extension can effectively compensate for hip flexion contractures up to about 15 degrees. When hip flexion contractures exceed 15 degrees (a common occurrence) or there is limited lumbar spine extension range available (also common) the patient is forced to adopt a forward trunk tilt in terminal stance in order to complete the step.
An alternative strategy used by some patients to compensate for limited hip extension is increased knee flexion and ankle dorsiflexion (a "crouch" position). This strategy is uncommon because it ends to be very fatiguing and may increase pain in patients with hip joint arthritis.

With either gait pattern, there remains difficulty in advancing the trunk forward in terminal stance, which results in a shortened step length on the opposite leg.

RX: Heat and stretch of anterior hip capsule & musculature to increase ROM; strengthen hip extensors in shortened range; use of UE aids to allow decreased muscular demands on hip and spine musculature.

Knee Flexion Contracture

COMMON ETIOLOGIES:

Patients with knee joint disease typically assume a resting posture of about 30 degrees of knee flexion as this decreases lateral forces and intra-articular pressure. The end result may be a knee flexion contracture.

"NORMALY":

During stance, the knee joint moves from a fully extended position to about 10-15 degrees of flexion as the limb is loaded in early stance. This is followed by extension back to an almost straight knee in midstance, and finally rapid knee flexion in preswing.

PATHOLOGICAL PRESENTATION:

Mild degrees of knee flexion contracture (i.e. less than 15-20 degrees) are often difficult to detect with visual observation. The primary abnormality is a lack of full knee extension in stance, making the leg functionally short. This abnormality is more pronounced with rapid walking as the absence of full knee extension functionally shortens the leg, giving rise to a "short leg limp" and a mild reduction in contralateral step length. As the flexion contracture increases to more than 20-30 degrees, the lack of midstance knee extension becomes increasingly obvious. With increasing severity of the contracture, it is more difficult to advance the GRF vector anterior to the knee, its normal midstance position. This will force an increase in the muscular demands placed on the quadriceps muscle to maintain weight bearing through a flexed knee. Forward trunk leaning is used by some patients to lessen the quad demand, but this has the effect of causing compensatory hip flexion and ankle dorsiflexion, which also increases muscle demands.

RX:

Heat and stretch of post-articular knee soft tissue to increase ROM (more difficult to achieve than increase in hip ROM);strengthen knee extensors in terminal extension; UE aids to decrease muscular demands.

Ankle Plantarflexion Contracture

COMMON ETIOLOGIES:

Most fixed ankle plantarflexion contractures are the result of prolonged passive positioning of the foot in plantarflexion (prolonged bed rest) or a result of prolonged positioning due to tone abnormalities. Dynamic loss of ankle range from plantarflexion muscle hyperactivity in UMN disorders results in similar biomechanical gait abnormalities.

“NORMALLY”:

During stance, the ankle joint moves from a neutral position (90 degrees) at heel strike to 10 degrees of plantarflexion as the limb is loaded. This is followed by rapid movement into dorsiflexion (need about 10-15 degrees of dorsiflexion range of motion) which continues through midstance and early terminal stance. The ability to dorsiflex the foot in midstance is essential in allowing the smoothly controlled forward rotation of the tibia which in turn allows for a normal, smooth forward progression of the trunk over the stance limb. During swing, plantarflexion to a neutral position is needed to allow foot clearance to occur.

PATHOLOGICAL PRESENTATION:

In stance, an ankle plantarflexion contracture prevents smooth forward movement of the trunk, making it difficult to "step" through and complete a normal gait cycle. At heelstrike, a plantarflexion contracture will result in an absent heelstrike and floor contact either flatfoot or with the forefoot depending on the severity of the contracture. Floor contact with the foot plantarflexed moves the center of pressure well anterior to its usual location in early stance. This moves the GRF vector anterior to the knee, resulting in inappropriate knee extension or hyperextension during the loading response.

Several patterns of gait abnormalities and compensatory strategies can be seen with plantarflexor contractures. When no other problems are present, healthy individuals will often simply walk on the forefoot (“toe walking”). This requires good strength and the ability to walk at reasonable speeds since inertia is used to facilitate the progression of' the trunk up and over the stance limb.
More typically, plantarflexion contracture occurs in combination with changes in muscle tone, strength, voluntary control or with other joint abnormalities. In this context, the ability to compensate is more limited. In these patients, the plantarflexed foot moves the GRF vector anteriorly far earlier in the gait cycle than normal. This results in early and prolonged knee extension (or hyperextension), often persisting though stance. At times, this can result in a rather forceful and rapid snapping of the knee into extension, the so called “extensor thrust”.

When the plantarflexed foot prevents or severely limits forward rotation of the tibia, it becomes difficult for the trunk to progress forward over the stance limb. Increasing forward trunk lean moves the COM over the stance phase limb that remains extended at the knee and plantarflexed at the ankle. As long as the COM does not move beyond the base of support and there is adequate proximal muscle strength o control the trunk motion, this strategy allows upright posture to be maintained. It is associated, however, with very short step lengths (“step to” gait), slow walking speeds, and is usually seen in moderate to severely disabled patients.

RX:

Prolonged stretch; serial casting to restore ROM; Achilles tendon lengthening; AFO if spasticity and dynamic posturing is primary problem; Adapt to deformity with use of heel wedge and shoe lift.

Antalgic Gait

Antalgic gait means that the pattern observed is a result of pain. Pain can cause a variety of responses, ranging from a lack of forceful activation up to a full blown flexor withdrawal reaction. In antalgic gait, the problem is chronic to one degree or another and the patient is attempting to compensate.

COMMON ETIOLOGIES:
Degenerative Joint Disease(DJD)/Osteoarthritis(OA), bony or soft tissue trauma, heelspur, etc.

PATHOLOGICAL PRESENTATIONS:
Most variants of antalgic gait tend to demonstrate generic features common to pain arising in many structures along with additional joint-specific abnormalities. The compensatory maneuvers used by patients are an attempt to achieve reduced weight bearing time on the painful limb, avoidance of impact loads, reduced joint excursion, and minimization of activity in muscles that cross the joint (decreases joint compressive forces). As a result, antalgic gaits from unilateral disease are characterized by slowed walking speed, asymmetry with a shortened stance phase on the painful limb, a tendency to stiffen the limb to avoid joint excursion, and an absence of forceful foot contact or pushoff.

Hip Pain

When pain is due to hip joint pathology, a common adaptation used during stance phase is to bend the trunk over the painful stance phase limb. This brings the COM closer to the joint's center of rotation (in the frontal plane), decreasing the joint compressive forces resulting from normal hip abductor activity. This gait pattern is essentially identical to the compensated gluteus medius gait described earlier. During swing phase, the hip is often carried in a mildly externally-rotated position, because this decreases tension on joint capsule. Patients with knee joint pain often keep the knee extended or in a slightly flexed position (especially if joint effusion is present) and the normal stance phase flexion-extension-flexion cycle of knee motion is absent or attenuated. There is a tendency to minimize knee extensor muscle activity in order to avoid joint compressive forces. Toe walking may be used to shift the GRF line anterior to the knee allowing passive stabilization without the need for knee extensor muscle activity. Some patients may carry the leg externally rotated during stance. This may be an alternate mechanism to passively stabilize the knee by using the collateral ligaments instead of knee extensor muscle activity.

Knee Pain

When motion of the knee is painful even without weight bearing, swing phase is characterized by a stiff knee that requires circumduction or vaulting for clearance, single leg stance is shortened (to compensate, the step length may be lengthened on the affected side).

Rx: Pressure relief = unweight the knee as much as possible. Assistive device

Arch Pain/Overpronation

The source of the pain is most commonly the attachment of the plantar fascia, the spring ligament, or the long plantar ligament.

COMMON SOURCES OF THE PROBLEM (ETIOLOGY): Overpronation, extended pronation, tight heelcord.

PATHOLOGICAL PRESENTATION:
May be very subtle, with no discernable gait deviation or perhaps a slightly decreased stance phase (or lengthened step) on affected side; most likely observation will be excessive rearfoot eversion during loading response and midstance, with pronounced medial protrusion of the talar head and collapse of the medial longitudinal arch; sometimes will manifest with weightbearing on the lateral surface of the foot (in an attempt to unweight the medial side).

Lower Limb Orthoses to Enhance Ambulation

Ann Yamane, M.Ed., CO/LO
University of Washington
Division of Prosthetics & Orthotics

OBJECTIVES

- Discuss the principles used in designing orthotic interventions for the lower extremity to restore mobility and function
- Identify orthotic components and relate their function and use to patient criteria
- Analyze the effect of orthoses on joint motion based on biomechanical needs during ambulation

OBJECTIVES

- Identify indications for use of specific orthosis designs based on goals related to
  - functional ambulation,
  - protection,
  - and contractures

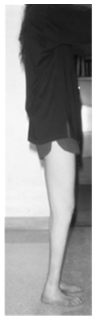
Role of Orthoses in the Rehabilitation Process

- Provide safe and efficient ambulation to access surroundings
- Maximize function
- Reduce long term effects of skeletal mal-alignment

Patient Assessment

The assessment aids in determining the biomechanical forces necessary to provide:

- Stable skeletal alignment
- Stable base of support to facilitate safe ambulation
- Substitute for impaired muscle strength
- Control unwanted motion from spasticity

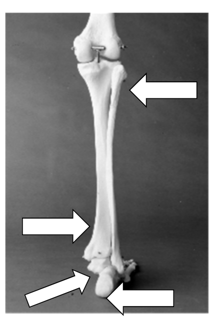


Biomechanical Principles

- Three-point force systems
- Ground reaction force force vectors
- Alignment
  - Tibial angle to floor
  - AFO/Footwear Combination (AFO-FC)

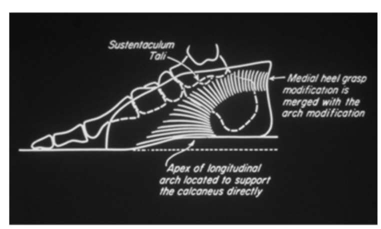
3-Point Force System
Subtalar Eversion Control

- Corrective Forces
  - Proximal to medial malleolus
  - Sustentaculum tali
- Counteractive Forces
  - Proximal lateral calf
  - Distal lateral calcaneus



3-Point Force Systems

Sustentaculum tali modification



Courtesy of Martin Carlson, CPO

3-Point Force System
Subtalar Eversion Control

- Corrective Force
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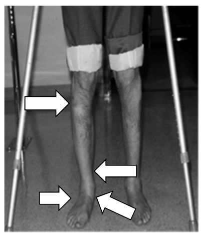

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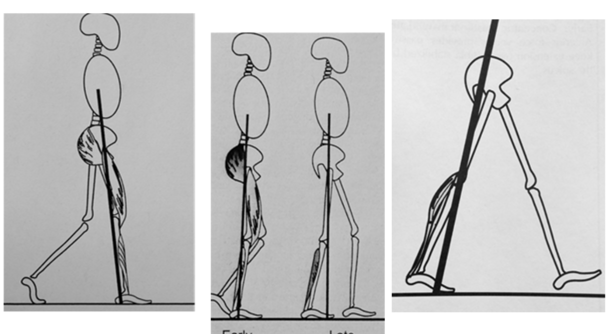
Describe the 3-point force system used to control excessive plantarflexion in a thermoplastic AFO?

a. posterior calf, plantar surface of the foot at the MT head region, ankle strap
b. posterior calf, dorsum of the foot, anterior calf
c. anterior calf, posterior calcaneus, dorsum of the foot
d. proximal lateral calf, medial malleolus, lateral calcaneus

Ground Reaction Force Vectors



Perry, J. Gait Analysis, 2010

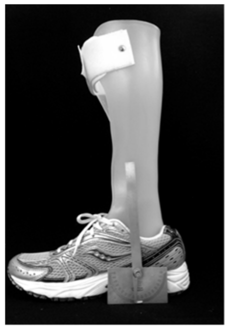
Tibial Angle to Floor

- Distal 1/3 of tibia/fibula to floor
- Considerations
  - Ankle joint ROM
  - Heel height of shoe

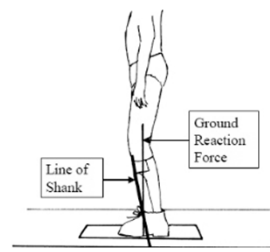
Tibial Angle to Floor

While wearing shoes

- Heel height
  - Differential from the ball of the foot to the heel
- Heel wedges may be used in the shoe to accommodate a plantarflexion contracture



AFO-Footwear Combination



Courtesy of Elaine Owen

- Shank vertical angle
  - Line of shank is along anterior tibial crest in relationship to vertical
  - Measurement taken with shoe
  - Evaluate overall postural alignment

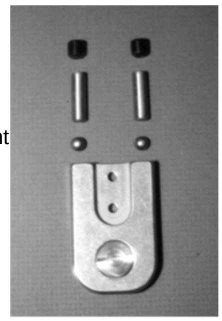
Anatomy of an AFO

- Stirrup
- Soleplate
- Sidebar/ Upright
- Calf band
- Pretibial shell

Anatomy of a Thermoplastic AFO

- Foot plate
  - Length
- Trim lines
  - Rigidity through position of trim lines at ankle region

Ankle Joint Controls

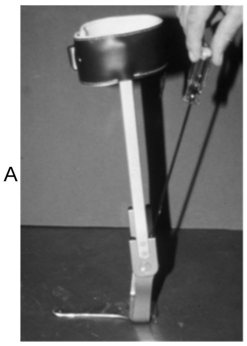


Double Adjustable / Dual Channel ankle joint

- Plantarflexion stop
  - Pin placed in the posterior channel
- Dorsiflexion stop
  - Pin placed in the anterior channel

Plantarflexion Stop

- Tilts the tibia anterior and positions the ankle joint in dorsiflexion
- Function
  - Provide clearance during swing phase
  - Produce a knee flexion moment at loading response



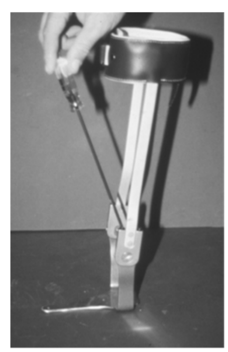
Dorsiflexion Weakness

AFO with a Plantarflexion (PF) Stop

- Provides stability in the sagittal plane by controlling ankle PF during swing phase
- Relationship between
  - adequate clearance during swing phase
  - knee flexion stability during loading response

Dorsiflexion Stop

- Limits dorsiflexion or tibial advancement
- Function
  - Create a knee extension moment midstance through terminal stance



Plantarflexion Weakness

AFO with a Dorsiflexion Stop

- Provides stability in the sagittal plane by controlling tibial advancement during midstance and terminal stance
- Relationship between
  - adequate clearance during swing phase
  - knee stability during stance phase

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An ankle-foot orthosis with a plantarflexion stop positioned in dorsiflexion will induce a/an

a. decreased knee flexion moment.

b. increased knee extension moment.

c. increased knee flexion moment.

d. increased hip extension moment.

W

Ankle Joint Controls

A

P

Double Adjustable / Dual Channel

- Spring placed in the posterior channel to allow controlled PF at loading response
- Pin placed in the anterior channel for a DF stop

Ankle Joint Controls

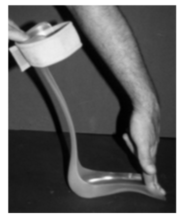
Ankle joint with a spring in the posterior channel

- allows PF ROM at loading response
- provides increased knee stability at loading response by decreasing the knee flexion moment

Ankle Joint Controls

Dorsiflexion Assist

Posterior Leaf Spring AFO



Functions:

- allow controlled plantarflexion at loading response and

- dorsiflexion ROM during late midstance and terminal stance

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Posterior Leaf Spring AFO

Indications:

- Dorsiflexion weakness
- Minimal need for stability of subtalar and midtarsal joints

Biomechanical goal:

- Limit unwanted plantarflexion ROM during swing phase

Carbon AFO Designs

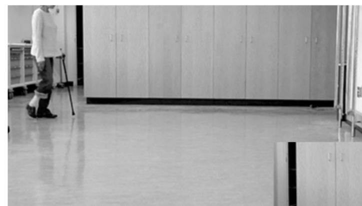
- Varied designs
  - Similar to Posterior Leaf spring
  - Rigid limiting dorsiflexion and plantarflexion
  - Prefabricated

Ankle Foot Orthoses


Custom fabricated
- Polypropylene
- Laminated
- Carbon
- Hybrid



Case Scenario-Hx of Polio




Biomechanical goals:
- DF during swing phase
- Stance phase stability

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Case Scenario-Hx of Polio

Clinical Considerations:
- Knee strength
- Activity level, function
- Leg length discrepancy
- PF contracture

Case Scenario-Polio



Custom fabricated carbon AFO
- Rigidity/flexibility
  - Ankle
  - Metatarsal heads

Lower Limb Orthoses
Categories based on Purpose

- Ambulation
  – To improve mobility and independence
- Protection
  – Protect or prevent further deformity
- Contractures
  – Reduce or prevent limitation of range of motion

Lower Limb Orthoses
For Ambulation

- Accommodative Foot Orthoses
  – Accommodate alignment and deformities
  – Lower durometer materials

Lower Limb Orthoses
For Ambulation

- Biomechanical Foot Orthoses
  – Coronal plane alignment control
  – Subtalar and midtarsal joint control

Lower Limb Orthoses
For Ambulation

UCBL FO

- (UC Biomechanics Lab Foot Orthosis)
- Indications:
  – Midtarsal pronation/supination, forefoot abduction/adduction
- Biomechanical goals:
  – Control of midtarsal and transtarsal joints

AFO Function
Clearance during Swing Phase

- Indications
  - Inadequate DF strength
- Design Options
  - DF assist
  - PF stop



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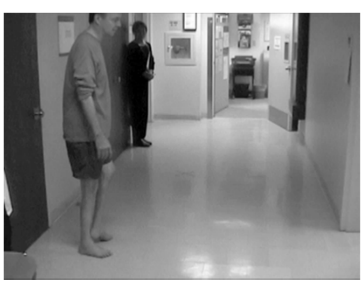
Dorsiflexion Weakness

- Clinical Observations
  - Absent heel strike if weakness <3/5
  - Adequate clearance during swing, foot slap at LR with 3/5
  - Clearance of the foot reduced during swing phase
  - Compensation with a steppage gait pattern
  - Instability of the subtalar joint

Case Scenario-CMT



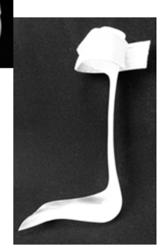
MMT:

- Weak DF, PF
- Good knee and hip

Biomechanical goals:

- Clearance during swing phase
- Subtalar joint control

Dorsiflexion Assist AFO

- Clinical Considerations:
  - DF ROM of the ankle joint since the design allows DF ROM midstance to terminal stance
  - Allows PF ROM at loading response
  - Stability of the subtalar, midtarsal, and transtarsal joints

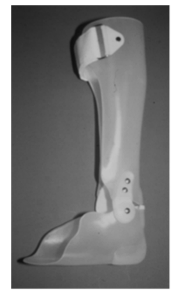
Articulated Plastic AFO
Plantarflexion Stop

- Indications:
  - Dorsiflexion weakness
  - Sagittal, coronal and transverse plane control
- Biomechanical goals:
  - Clearance of the foot during swing phase
  - Stability of the subtalar, midtarsal joints
  - Allow DF/tibial advancement

Articulated Plastic AFO
Plantarflexion Stop

Clinical Considerations

- Produces a knee flexion moment at loading response dependent on tibial angle to floor or shank vertical angle
- Trade off between clearance of the foot during swing and knee stability during stance phase



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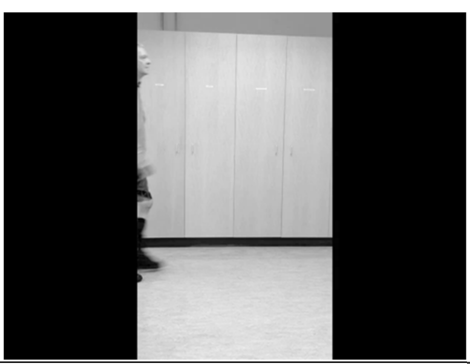
Case Scenario-CMT



Solid Ankle AFO

- Biomechanical goals:
  - Clearance of the foot during swing phase
  - Control of dorsiflexion/tibial advancement
  - Provide stability of the subtalar and midtarsal joints

Solid Ankle AFO

- Indications:
  - Combined dorsiflexion and plantarflexion weakness
  - Sagittal, coronal and transverse plane control

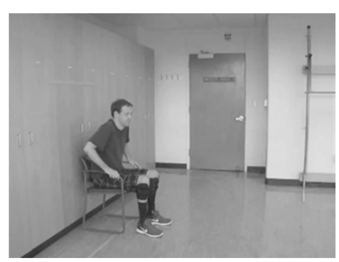
Solid Ankle AFO

- Clinical Considerations
  - Fair quadriceps strength to control destabilizing knee flexion moment at loading response (LR)
  - Shoe modifications to reduce knee flexion moment at LR
    - Bevel heel
    - Cushion heel
    - Rocker sole

Carbon AFOs

- Custom Fabricated
  - Determine PF/DF resistance
  - Footplate length/flexibility

Case Scenario
Spinal Muscular Atrophy



MMT:
- No DF or PF strength

Biomechanical goals:
- Clearance of foot during swing phase
- Substitute for PF during stance phase
- Tri-planar control

Plastic Ground Reaction AFO

- Design Characteristics
  - Solid ankle with pretibial shell
  - Tibial angle 90 degrees to floor with shoes
  - Shank vertical angle with shoes
  - Extended footplate
- Indications:
  - Quadriceps weakness (3-/5)
  - Plantarflexion weakness

Plastic Ground Reaction AFO

Biomechanical goals:

- Provide knee extension moment midstance through terminal stance

Considerations:

- Creates a knee flexion moment at loading response

Articulated Ground Reaction AFO

- Spring in the posterior channel
- Stop in the anterior channel
- Reduces knee flexion moment at loading response

Articulated Ground Reaction AFO

- Indications:
  - Weak plantarflexors
  - Weak quadriceps
  - Weak hip extensors
- Biomechanical goals:
  - Provide a knee extension moment midstance through terminal stance
  - With a spring in the posterior channel, decrease the knee flexion moment at LR

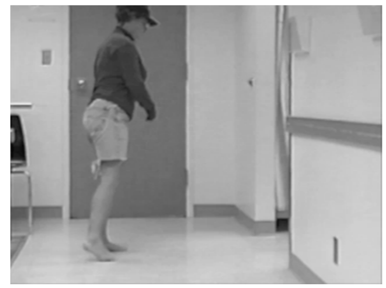
Case Scenario
Stroke

Biomechanical goals:

- Prevent mal-alignment and deformities
- Substitute for muscle weakness/motor control
  - Ankle joint
  - Subtalar joint
  - Forefoot
  - Knee
  - Hip

Case Scenario-Stroke

- Affect sagittal plane control at the knee by ankle position and control
  - Hyperextension
  - Flexion



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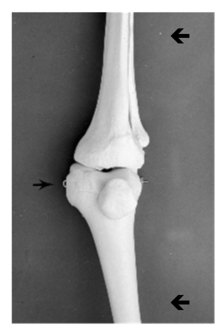
Knee Ankle Foot Orthosis

- Indicated for control at the knee
  - Valgum
  - Varum
  - Recurvatum
  - Quadriceps weakness

Knee Ankle Foot Orthosis

Genu valgum 3-point force system

- Corrective force
  - Medial femoral condyle
- Counteractive forces
  - Lateral proximal thigh
  - Lateral distal calf



Knee Ankle Foot Orthosis

Recurvatum control

- 3-point force system
- Plantarflexion stop

Knee Ankle Foot Orthosis

- Indicated for use with less than 3-/5 Quadriceps strength OR bilateral weakness

Bilateral KAFO's

- Locked knee joints
- Ankles locked in dorsiflexion
- Weight line maintained posterior to hip joint to provide stability at the hips

Knee Ankle Foot Orthoses Components

- Ankle joints
- AFO section
- Thigh section
- Infrapatellar and suprapatellar straps
- Knee Joints

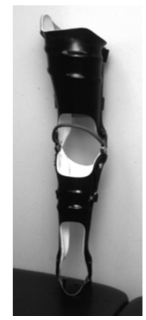
Knee Joints

- Bail Lock
- Drop Lock
- Offset Free Knee

Knee Joint Components

Bail Lock

- Easier to unlock when moving from standing to sitting
- Consider use with
  - bilateral KAFOs
  - decreased hand function



Knee Joint Components

- Drop Lock/Ring Lock
  - Good hand function required to operate
  - Freely falls into locked position when fully extended

Knee Joint Components

Offset Knee Joint

- Provides increased knee stability during stance phase
- Mechanical knee axis aligned posterior to anatomical knee joint axis

Knee Joint Components

- Offset knee joint optimal function
  - Approximately 10 degrees plantarflexion ROM at loading response
  - Incorporate a dorsiflexion stop at the ankle joint

Quadriceps Weakness

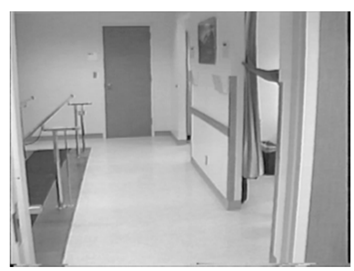
- Clinical Observation
  - Mild to moderate weakness
    - Eliminate knee flexion by maintaining knee extension at initial contact
  - More severe weakness
    - Forward trunk leaning
    - genu recurvatum

Quadriceps Weakness

- Cauda Equina Injury
- No intervention for many years

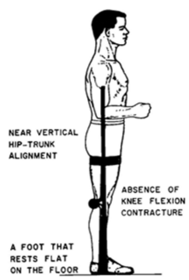
Quadriceps Weakness
Offset Free Knee KAFO

- Dorsiflexion stop
- Plantarflexion stop
  - Posterior spring
- Degree of recurvatum determined for stability
- 3-pt. Force system



Offset Knee Joint KAFO Indications

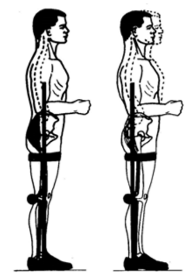
- Unilateral involvement
- Vertical hip-trunk alignment
- Absence of contractures
  - Knee and hip
- Plantargrade foot
- Quadriceps weakness
- Hip strength 2/5 or >
- Joint proprioception



Lister, MJ, Principles LE Bracing, 1967

Quadriceps Weakness Offset Knee Joint KAFO Option

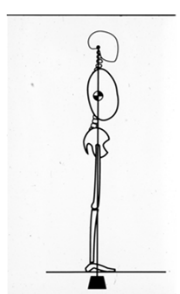
- Center of mass in relationship to mechanical knee joint axis
  - Hip extensor strength most effective



Lister, MJ, Principles LE Bracing, 1967

Quadriceps Weakness

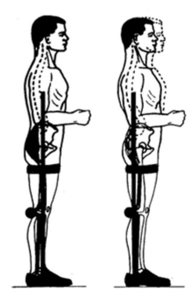
- Quadriceps strength
  - at least 3-/5 or 3/5
- Center of mass must be maintained anterior to knee joint axis
  - ground reaction force vector for knee stability



Perry J, Gait Analysis, 1992

Offset Knee Joint KAFO Stability

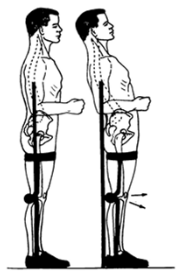
- Center of mass maintained anterior to the mechanical knee joint axis
  - mechanical knee joint moves into extension
  - hip extensor strength necesary



Lister, MJ, Principles LE Bracing, 1967

Offset Knee Joint KAFO Instability

- If the Center of mass passes posterior to mechanical knee joint axis, the mechanical knee joint flexes

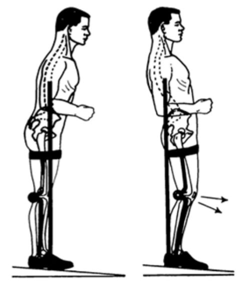


Lister, MJ, Principles LE Bracing, 1967

Offset Knee Joint KAFO Instability on Inclines

Weak hip extensors or trunk extension

- Center of mass falls posterior to mechanical knee joint axis
- Knee flexion instability



Lister, MJ, Principles LE Bracing, 1967

Offset Knee Joint KAFO Instability

- Uneven ground
  – Elevation under heel of shoe

Lister, MJ, Principles LE Bracing, 1967

KAFO with Offset Knee Joints

- Advantages
  – Ease in rising from a chair
  – Ease in walking due to lack of knee locked in extension
- Disadvantages
  – Uneven ground instability
  – Difficulty in going down inclines
  – Cognitive demand

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What muscle group is assessed to determine if an individual with quadricpes weakness would be able to successfully utilize a unilateral KAFO with an offset knee joint?

a. ankle dorsiflexors
b. hip flexors
c. abdominals
d. hip extensors

Quadriceps Weakness
AFO Option

- Hip extensor strength 3/5
  - Pre-tibial shell, DF stop
- Knee extensor strength 3-/5
  - Pre-tibial shell, DF stop
  - Spring in posterior channel DAAJ

Quadriceps Weakness
AFO with DF stop

- DF stop limits ankle dorsiflexion
  - midstance to terminal stance

AFO with DF stop
PF stop/spring

- Controlled PF ROM
  - spring in posterior channel
  - decreases knee flexion moment at loading response

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A patient with fair minus quadriceps strength wearing a ground reaction ankle-foot orthosis will have knee extension facilitated from midstance to terminal stance by utilization of a

a. plantarflexion stop
b. dorsiflexion assist
c. dorsiflexion stop
d. plantarflexion resist

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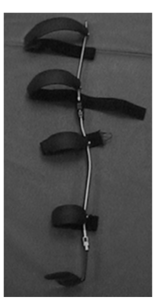
Stance Control KAFOs

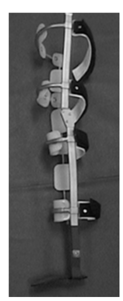
- Method of activation
  - Ankle, gait
- Many recommend use with 3/5 hip extensors
- <10-15 degrees genu valgum
- Knee flexion contractures <10 degrees
- Achieve knee extension at terminal stance
- Unilateral
- Varied weight limits

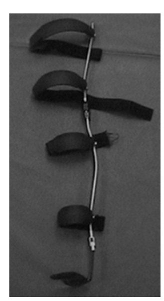
Stance Controlled Knee Joints



- Ability to flex knee during swing phase
- Stabilization with a locked knee during stance phase
- Limited designs have stabilization of knee with flexion

Stance Controlled Knee Joints





Tubular upright houses cables
- Full extension locks the joint
- Unlocks at terminal stance with
  - 5-10 degrees DF ROM
  - Knee extension

Recommendations
- 3/5 hip extensors
- <5 degrees knee flexion contracture

Stance Controlled Knee Joints

- Ankle joint with dorsiflexion ROM to unlock knee joint
- Full extension locks knee at terminal stance

Stance Controlled Knee Joints

- Create knee extension moment during terminal stance with
  - active muscle control of hip extensors, plantarflexors
  - passive orthotic control
    - DF stop
    - Longer footplate length
    - Rocker fulcrum moved distally on the shoe

Stance Controlled Knee Joints

Stance Phase Lock

- Pendulum
- Full extension unlocks knee for swing phase
- 3/5 hip extensors recommended

Stance Controlled KAFOs

- Trial orthoses are available from most companies

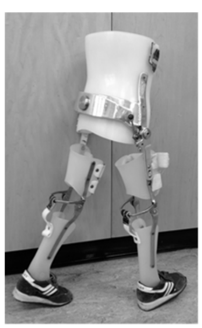
HKAFO

- Sagittal, coronal, and transverse plane control

Reciprocating Gait Orthosis

- Pelvic band and connected hip joints
- Hip flexion or trunk extension on one side facilitates hip flexion on the contralateral side
- Used in conjunction with KAFOs or AFOs

RGO



Orthoses for Protection

- Goal:
  - Protect or prevent further deformity
    - Fracture bracing
    - Knee orthoses
    - Hip orthoses
    - CROW
    - PRAFO

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Fracture Bracing

- General Principles
  - Protection/immobilization of the injured area through soft tissue compression
  - Mobilization of the patient once acute symptoms subside
    - ROM of adjacent joints
    - Muscle function
  - Graduated weight bearing

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Fracture Bracing

- Tibial diaphysis fractures
- Used post cast application (7-10 days)
- Orthosis will not address shortening
- Considerations
  - Apex anterior or posterior angulation
  - Tibial fx without fibular fx
  - Above tibial tubercle, distal tibial fx

Orthosis Design

- Prefabricated
- Thin, well conforming anterior section
  - 1/4” foam padding
- Foot section
  - Maintain heel in correct AP position
  - Maintain suspension
- Posterior calf flattened

Courtesy Wheaton Brace Co.

Ankle Foot Fracture Orthoses

- Immobilization of the affected area
- Rocker bottom to aid in smooth roll-over
- Circumferential Compression
- Post-operative rehabilitative orthosis
- Available in various styles with fixed and adjustable ankle ROM

Femoral Fracture Orthoses

- Distal 1/3, tibial plateau fx
- Provides for variable ROM at the hip and knee
- Free Motion at the ankle
- Circumferential compression
- Does not limit internal or external rotation at the hip

Hip, Knee, Ankle, Foot, Ankle Orthosis (HKAFO)

- Proximal Femoral Fractures
- Available prefabricated or custom to measurements
- Various joint selection available for hip and knee
- Limits internal and external rotation at the hip
- Circumferential compression

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Three Categories of Knee Orthoses

Prophylactic
- Attempt to prevent or reduce severity of knee ligament injuries

Rehabilitative
- Protect motion of injured knee or post-op

Functional
- Provide stability during activities

Knee Orthoses for OA

- Pre-fabricated and custom fabricated designs
- Uni-compartmental involvement

Hip Orthoses

Courtesy TLC Hip Abduction Brace

- Pre-fabricated designs
- Adjustable
- Use of heel cup extension if rotational control desired

CROW

- Charcot Restraint Orthotic Walker
- Goal:
  - Reduce pressure on specific areas of the plantarsurface of the foot
  - Rocker sole facilitates normal gait pattern

PRAFO

- Pressure Relief AFO
- Pre-fabricated
- Reimbursement guidelines
  - Not covered for addressing heel ulcers
  - Covered for plantarfasciitis, and contractures up to 45 degrees with 10 degrees PROM, active stretching program, interfering with functional abilities

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Objectives

- Discuss the principles used in designing orthotic interventions for the lower extremity to restore mobility
- Identify orthotic components and relate their function and use to patient criteria
- Analyze the effect of orthoses on joint motion based on biomechanical needs

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Objectives

- Identify indications for use of specific orthoses designs based on the categories of ambulation, protection, and contractures

Upper Limb Orthoses

Sue Spaulding, MS, CPO
University of Washington
Division of Prosthetics & Orthotics

Outline

1. Why prescribe upper limb orthoses
2. Review prehensile function and grasp patterns
3. Consider orthotic mechanical principles
4. Describe indications and goals for UL components and orthoses

What do we use our upper limbs for?

Basic ADLs
– Self-feeding
– Dressing
– Bathing
– Toileting

Mobility needs
– Transfers
– Transitional movements
– Crutch walking
– Wheeled mobility

Movement:
- Reaching
- Prehension
- Manipulation

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Why prescribe UL orthoses?

- Patient's perspective
  – Hand function is a priority (Snoek et al., 2004).
  – Recovery of even partial arm and hand function impacts independence and QOL (Anderson, 2004).
- Aging Effects on UL Function
  – Pain
  – Contractures
  – Upper limb musculoskeletal injuries

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Criteria for Efficient Prehensile Function

1. Stable wrist
2. Two opposing digits
   - Thumb opposition
     - Abductor Pollicis Brevis
     - Opponens Pollicis and superficial head of FPB
   - Stable index and third finger
   - Moveable ring and small finger
3. Palmar mobility
4. Sensation
5. Pain free

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What is this prehension pattern?

a. Cylindrical
b. Tip
c. Lateral/key
d. Three jaw chuck
e. Hook
f. Spherical

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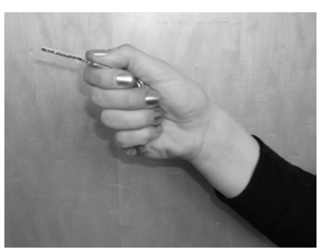

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ULO Mechanical Principles

- Force vectors
- Lever arms
- Torque
- Pressure over skin
- Surface contours
- Stress concentrations

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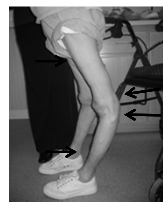
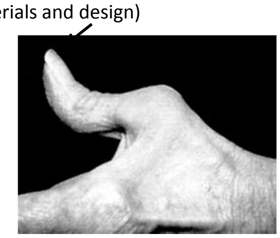
ULO Mechanical Principles

- Force vectors (3 point force)
- Lever arm
- Pressure distribution (materials and design)





- Corrective Force Torque > Internal Joint Torque

Terminology

Static

- Therapeutic
  - Static FO, thumb spika, HO, WHO, RO, SEO, SEWO
- Functional
  - Task specific WHO and HO

Dynamic

- Therapeutic
  - Dynamic FOs, WHO, EO
- Functional
  - Ratchet WHO, Wrist driven WHO, MAS

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IP Joint Instability

- Diagnoses
  - Ligament strain: M-L instability at IP joint
  - Mallet finger: Extensor tendon avulsions of the distal phalanx
  - Arthritis
    - Boutonniere deformity: Central slip disruption of the PIP joint
    - Volar plate avulsion of the PIP
  - Fractures: phalanx
- Orthotic Goal
  - Immobilization of the affected joint(s)
- Orthosis: Static finger splints

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Static Finger Orthoses

Courtesy of Trulife

Courtesy of Health Products for You

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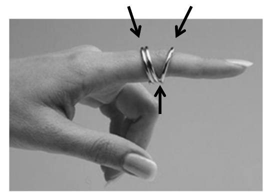
Finger Rings



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IP Joint Contracture

- Pathology
  - Arthritic fingers: swan neck or boutonniere's
  - Post-operatively
  - Normal motor, sensory and potential for ROM
- Goals
  - Properly position joints, decrease inflammation, rest and support weakened structures, to improve function through better stability and position, to prevent joint contractures and to aid post-op
- Orthosis: Static or dynamic finger splints

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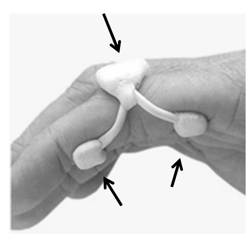
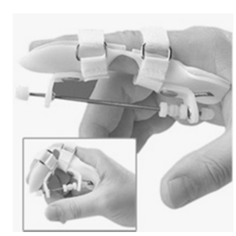
Dynamic Finger Orthoses





Courtesy of Health Products for You

Tenderness at 1st MCP or CMC joint

- Pathology
  - Arthritis: joint inflammation and tenderness
  - Strength and sensation normal
  - ROM limited by pain
- Goal
  - Pain relief through joint immobilization
- Orthosis: Thumb spica

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Thumb Spica

Courtesy of Health Products for You

Bani, MA et.al. *The effect of custom-made splints in patients with the first carpometacarpal joint osteoarthritis.* POI 2013.

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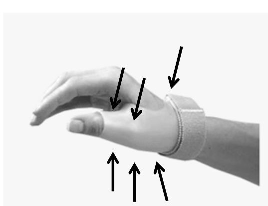
Thumb Spica



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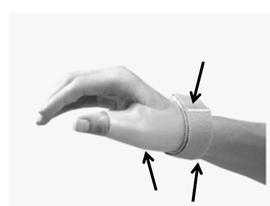

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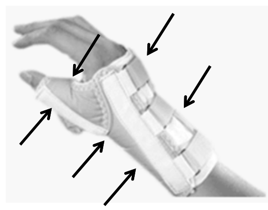

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Finger MCP Joints

- Signs/Symptoms
  - Ulnar peripheral nerve palsy
  - RA: MCP Joint subluxation
- Goal
  - Avoid MP extension contracture
  - Pre-position the hand for grasp
- Orthosis: "Knuckle bender" dynamic hand orthosis with MP Stop (lumbrical bar)

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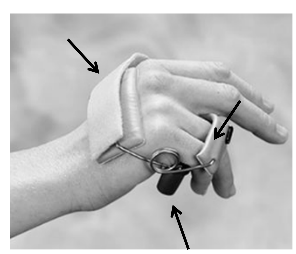
MP Stop Hand Finger Orthosis "Knuckle Bender"



Courtesy of Health Products for You

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Intrinsic Musculature Weakness

- Findings
  - Inability to position the thumb in opposition
  - Strong wrist extensors
- Goal
  - maintain a functional position of the hand and prevent deformities
- Orthosis: basic opponens
  - Various attachments can be added for eating, reading or grooming

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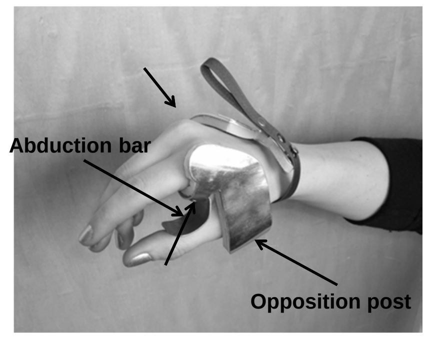
Basic HO Opponens



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Weakness or paralysis of wrist and hand musculature

- Pathology
  - C1-5 quadriplegia with 0 wrist extensors and an intrinsic minus hand
- Goal
  - Provide light-weight support of the wrist, position finger/thumb in opposition, maintain functional architecture, prevent wrist/hand deformities
- Orthosis: Long Opponens WHO

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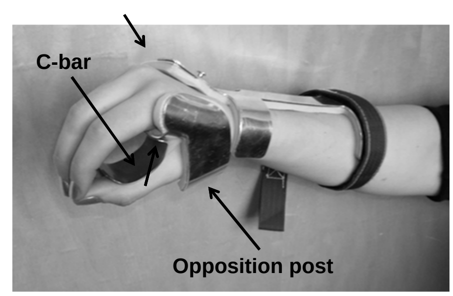
Long Opponens WHO



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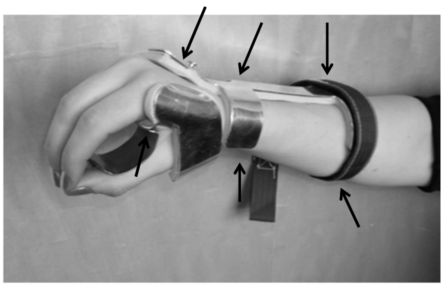
Long Opponens WHO



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Good extensors but no grasp

- Findings
  - Wrist extensor strength 3+ or better and good proximal strength; Finger flexor strength absent
  - C6 and C7 quadriplegia
  - Motivation of the patient
- Goal
  - Allow grasp through support of the wrist, positions finger/thumb in opposition, maintains functional architecture
- Orthosis: Wrist driven WHO
  - May interfere with wheelchair propulsion

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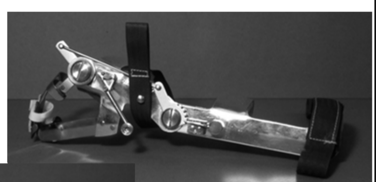
Wrist Driven - WHFO

Tenodesis orthosis, flexor hinge splint



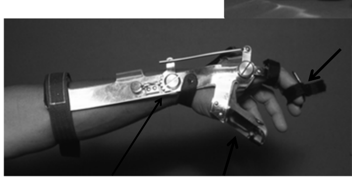


Photo Courtesy of Ann Yamane

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No Extension or Flexion Strength

- Findings
  - Shoulder strength of 3+ or better (or use with MAS)
  - C5 quadriplegia with no hand or wrist extension/flexion strength
  - Motivation
- Goal
  - Allow grasp and release of objects
- Orthosis: Ratchet WHO

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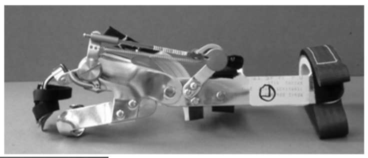
Ratchet - WHFO



Ratchet

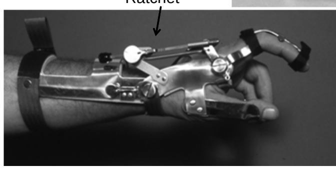


Photo Courtesy of Ann Yamane

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Wrist/Hand Pain or Minor Weakness

- Signs/Symptoms
  - Compression of median nerve; incomplete motor/sensory loss (i.e. Carpal Tunnel Syndrome)
- Goal
  - Relieve pain through immobilization
  - Wrist positioned in neutral flexion/extension
- Orthosis: Wrist hand orthosis; “cock-up splint”

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Static WHO – Cockup Splint

Short Cockup Splint

Long Cockup Splint

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Ulnar drift

- Signs/Symptoms
  - Rheumatic joints and muscle imbalance
  - Prior to ulnar drift and palmar subluxation
- Goal
  - Maintenance of MP joint alignment
- Orthosis: Ulnar deviation orthosis

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Ulnar Deviation Orthosis

Courtesy of Trulife

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Flexion of wrist and fingers

- Findings:
  - Motor and sensory may be present or absent
  - CVA: Flexion synergy
  - Lower Brachial Plexus Injury: Motor deficits
- Goal
  - Prevent contractures
  - Stabilize wrist and fingers in neutral position
- Orthosis: Static Wrist Hand Finger Orthosis
  - Wrist may be positioned in flexion; MCP positioned in flexion; IP joints extended; Thumb in opposition

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WHFO Resting Splint

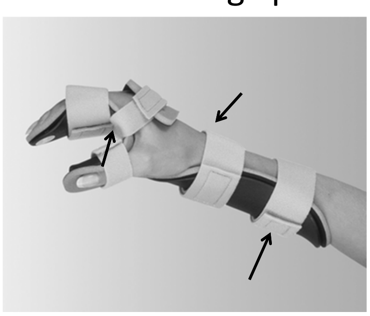

Photo Courtesy of RCAI

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WHFO Resting Splint

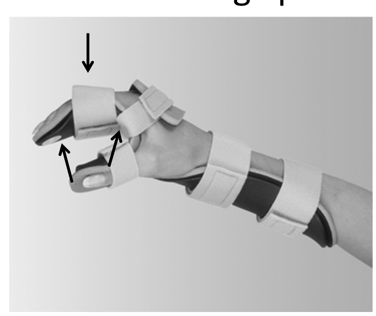


Photo Courtesy of RCAI

WHFO Resting Splint

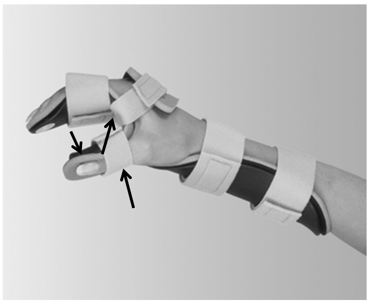
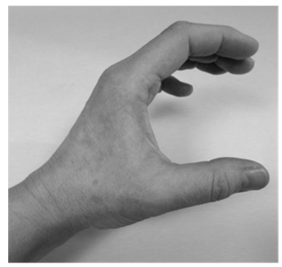


Photo Courtesy of RCAI

Positioning of the Hand

Functional Position



Antideformity (intrinsic-plus) Position

Soft tissue length changes are associated with joint positioning

Supporting WHO Research

- A volar wrist support in 30-35' of extension improves grips strength and/or efficiency. *(J Hand Surg 1992, Arch Phys Med 1999, J Neurol 2005, NeuroRehab 2007)*
- Thumb positioning orthosis assists with pinch. *(Arch Phys Med 1983, Adv Exp Med Biol 1987, Prosth Orthot Int 2013)*
- Contracture prevention *(Phys Med Rehab Clin N Am 1998)*
- Pain *(Phys Ther 1998)*

Early intervention, multidisciplinary approach and include patient in the plan of care.

PNI: Position depends on diagnosis

Orthosis	Position
Radial N. Injury	
Wrist immobilization orthosis	Wrist in 30-40' extension
MCP extension WHO	Wrist in 30-40' ext; MCPs in dynamic ext
Tenodesis orthosis (Wrist driven orthosis)	Dorsal base using tenodesis effect with
Ulnar N. Injury	
Elbow orthosis	Elbow in 30-45' flexion
Anticlaw orthosis	4th and 5th MCPs in 30-40' flexion
Median N. Injury	
Dorsal or volar WHO	Wrist in neutral
Ulnar gutter WHO	Wrist in neutral
Thumb web spacer orthosis (C bar)	Thumb in 40-45' palmar abduction

(Coppard Lohman 2014)

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Wrist and Finger Extension Weakness

- Signs/Symptoms
  - Post-op after finger joint resection arthroplasty
  - Radial Nerve Injury at elbow
- Goal
  - Stabilize wrist
  - Control motion in the desired plane and range
  - Assist flexion/extension without hyper-motion
- Orthosis: dynamic WHFO with outriggers and bands

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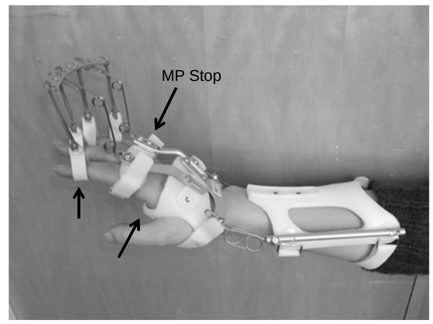
Dynamic WHFO with Ext Assist



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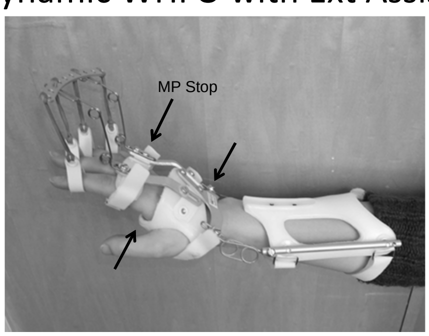
Dynamic WHFO with Ext Assist



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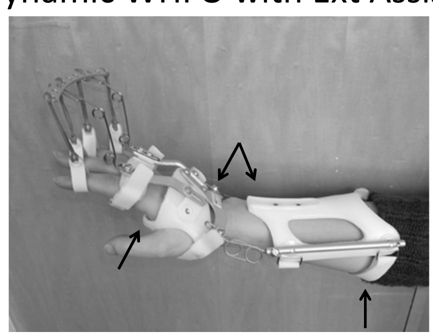
Dynamic WHFO with Ext Assist



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Task Specific Orthoses or Universal Splint

- Signs/Symptoms
  - Deformity or weakness that prevents prehension
- Goal
  - To perform a specific task
- Orthosis: task specific orthosis

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Task Specific Orthoses

Courtesy of Health Products for You

Healthmegamall

Photo Courtesy of Texas Assistive Devices

↗Placement, depends on task

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Shoulder Weakness

- Findings
  - Absent or weak elbow flexion, shoulder flexion, abduction and external rotation, limited endurance
  - E.g. MD, Polio, Cervical spinal cord lesion, Guillain-Barre, ALS
  - Some residual muscle strength (MMT at least poor or grade 2) and coordination of elbow flexion (can be used for C5 quad)
  - Adequate strength and ROM to move the MAS: neck, trunk, shoulder girdle and elbow
- Goal: Assist shoulder elbow motions
- Orthosis: MAS

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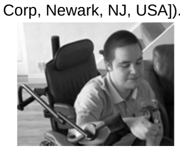
Mobile Arm Support (MAS)

Balanced forearm orthoses

WREX - Wilmington Robotic EXoskeleton

Photo Courtesy of Jaeco

DAS (Dynamic Arm Support, [Assistive Innovations Corp, Newark, NJ, USA]).



ARMON (Assistive Innovations Corp, Newark, NJ, USA

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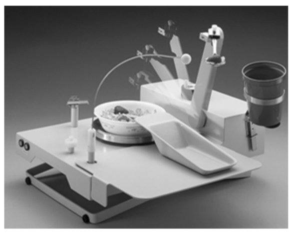
Powered Arms

iARM

(Assistive Innovations Corp, Newark, New Jersey; formerly known as the Manus)



Windsor Feeder

https://www.ncmedical.com

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Elbow ROM and Stability

- Signs/Symptoms
  - Stable fractures, post-trauma or post-surgery, elbow dislocation, predisposal for contracture, strains, sprains and muscle trauma, avoidance of elbow contractures
- Goal
  - Immobilization for soft tissue repair or boney callous formation, reduce soft tissue contractures
- Orthosis: Elbow orthosis
  - May be fabricated with turnbuckle and/or locking joints

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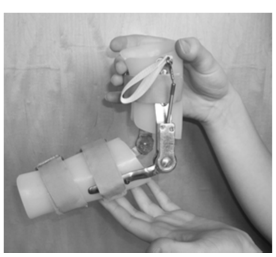
Elbow Orthosis

Locking Hinge



Adjustable Hinge

Photo Courtesy of RCAI

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Post-Op Shoulder

- Signs/Symptoms
  - Post rotator cuff repair, anterior-posterior capsular repairs and post-manipulation
  - Axillary burns
- Goal
  - Protect soft tissues; Prevent contractures; Limit motion at glenohumeral joint, maintain abduction position
- Orthoses
  - Shoulder abduction pillow
  - Airplane orthosis

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Shoulder Abduction Pillow

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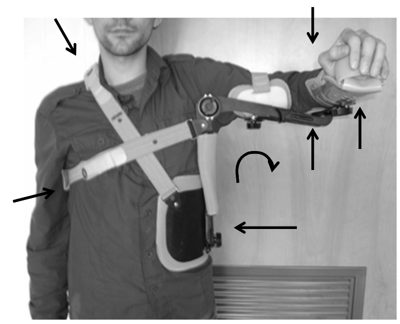
Airplane



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Long-term Shoulder Elbow Support

- Signs/Symptoms
  - Brachial plexus injury, painful subluxing shoulder joint
- Goal
  - Unweight the arm to support the shoulder joint
- Orthosis: Gunslinger

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Gunslinger

Photo Courtesy of Trulife

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Givmohr Sling

- Reduction of subluxation in sitting and standing.
- Reduction of shoulder pain.
- Dynamic joint compression of shoulder, elbow and wrist during standing and ambulation to facilitate return.

http://www.givmohrsling.com/

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Sport Sprain

- Signs/Symptoms
  - Shoulder Sprain
  - AC separation
- Goal
  - Limit motion at the end range, allow movement and activity
- Orthosis: Shoulder orthosis

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Shoulder Stabilizer

Sawa Shoulder Stabilizer

Photo Courtesy of Smith & Nephew, Inc.

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Questions

- What is the most famous fracture of the radius?
  a. Scaphoid
  b. Colles
  c. Lunate
- Which carpal bone is most frequently fractured?
  a. Scaphoid
  b. Colles
  c. Lunate
- Which carpal bone is most frequently dislocated?
  a. Scaphoid
  b. Colles
  c. Lunate

Fractures

- Signs/Symptoms
  - Mid-humeral fracture
  - Forearm fracture
- Goal
  - Immobilization
- Orthosis: Humeral fracture orthosis or forearm fracture orthosis

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Humeral Fracture Orthosis

Forearm Fracture Orthosis

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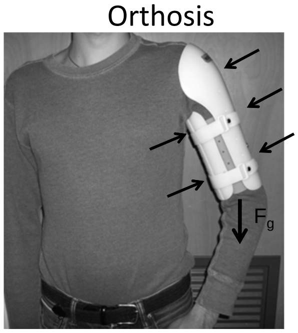
Humeral Fracture Orthosis



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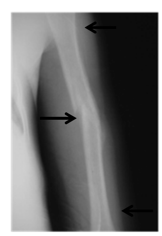
Humeral Fracture Orthosis



Varus deformity during healing due to upward force at elbow.

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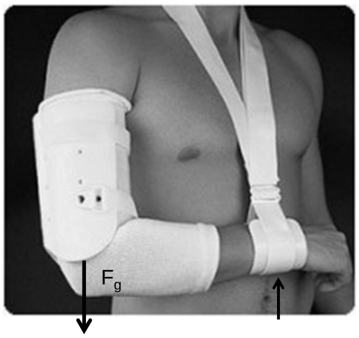
Humeral Fracture Orthosis



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New Technologies

- Neuromuscular arm dysfunction: Myopro arm orthosis with myoelectric control, from a patient's biceps and triceps, controls an elbow wrist hand orthoses
  - Muscle re-education
  - Maintain or increase ROM

- Tremors: WOTAS (wearable orthosis for tremor assessment and suppression)

Myopro arm

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Side Effects

- Decreased muscle strength and endurance after immobilization
- Skin breakdown

Patient education and follow-up are critical
- Purpose of the splint, donning/doffing, care
- Break-in schedule to develop skin tolerance
- Targeted training

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Summary

- Why?
  - Basic ADLs, Mobility Needs, Functional tasks
  - Anticipate future rehab needs (e.g. aging, overuse)
- How?
  - Mechanical principles
- What?
  - Patient-specific orthosis
  - Targeted training

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References

- http://www.ncbi.nlm.nih.gov/books/NBK27177/
- http://www.scireproject.com/rehabilitation-evidence/upper-limb/summary
- http://www.ebrsr.com/reviews_details.php?31
- Tyson SF, Kent RM. The Effect of Upper Limb Orthotics After Stroke: A Systematic Review. NeuroRehabilitation 28 (2001) 29-36.
- Prokop LL. Upper Extremity Orthotics in Performing Artists. Phys Med Rehabil Clin N Am. 17 (2006) 843-852.
- Atlas of Orthoses and Assistive Devices

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Manufacturers

- Restorative Care of America:http://www.rcai.com/index.html
- Texas Assistive Devices: http://www.n-abler.org/N-AblerII/N-Abler_III_WHO.htm
- North Coast Medical: https://www.ncmedical.com/categories/Upper-Extremity_24.html
- Health Products for You:http://www.healthproductsforyou.com/
- Jaeco Orthopedic: http://jaecoorthopedic.com/products/
- DonJoy: https://www.djoglobal.com/our-brands/donjoy
- Trulife: http://trulife.com/all-products/orthotics
- Givmohr: http://www.givmohrsling.com/

Rehabilitation of the Lower Extremity Amputee

Natalie Cooper, MD
Amputee Rehabilitation Fellow
VA Puget Sound Medical Center
Department of Rehabilitation Medicine
University of Washington

Objectives

- At the end of this lecture, the learner will be able to:
  - State the common causes of limb loss in the US
  - Describe various amputation levels
  - Describe post-op complications in dysvascular and traumatic lower extremity amputees
  - Compare and contrast the functional outcomes of dysvascular and traumatic amputees
  - Develop an appropriate rehabilitation plan for an amputee patient during the pre-prosthetic phase

Epidemiology of Limb Loss

- estimated 185,000 amputations per year in the US
- 2005: 1.6 million persons in US living with limb loss
- 2050 -> 3.6 million amputations
- 2009 -> hospital costs associated with amputation totaled more than $8.3 billion in the United States.

Graham et al, Arch Phys Med Rehabili Vol 89, March 2008; Varma et al, Phys Med Rehabil Clin N Am 25 (2014) 1–8

Etiology

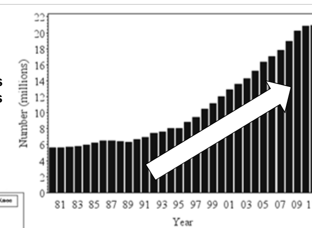
- 4 main categories
  1. Dysvascular(PVD and/or DM)
  2. Trauma
  3. Cancer
  4. Congenital

Dysvascular (PVD and DM)

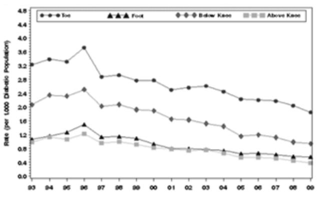
- Epidemiology*
  - 1988 – 1996 -> an average of 133,735 hospital discharges for amputations per year
  - 82% of limb-loss related discharges were for dysvascular causes
  - 27% increase over the study period
  - Vast majority (97%) were lower limb
    - 25.8% AKA
    - 27.6% BKA
    - 42.8% Other (toes, partial foot, etc)
  - Increased risk in males and African-Americans

*Dillingham et al, South Med J, 2002

- the number of adults diagnosed with DM has tripled since 1980s
- significant increase in new diagnoses btwn mid-1990's to mid-2000'sreflects improved
- introduction in diabetes screening programs



Number of Patients with Diagnosed DM

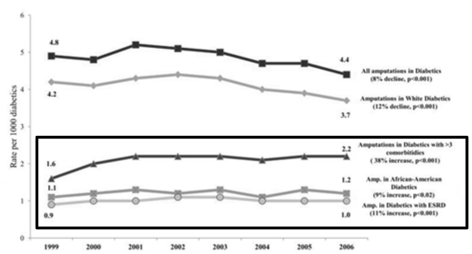


Rate of Hospital Discharge for Diabetic Patients Following LE Amputation

- rate of LE amputations in diabetics has been decreasing since 1996
- introduction of diabetic foot screening programs

Source: CDC

Source: CDC



- the amputation rate declined overall among patients with diabetes
- increased incidence of amputations among :
  - patients with 3+ comorbidities
  - patients with end-stage renal disease (ESRD)
  - African American patients

Goldberg et al, J Vasc Surg. 2012 Dec; 56(6): 1663–1668

Trauma

- 2nd most common cause of amputations
- incidence declining overall
  - increased limb salvage
  - safer cars
  - higher occupational health standards
  - quicker emergency response services
- vast majority (68.6%) are upper extremity

Varma et al, Phys Med Rehabil Clin N Am 25 (2014) 1–8

Trauma

- Males > females
- Age: bimodal distribution
  - < 30 y/o -> MVC, occupational accidents
  - > 70 y/o - > falls

"Ultimate Men's Health Guy" Noah Galloway, Nov 2014

- Post-war returning veterans:
  - 6000 amputations in Vietnam
  - 1715 amputations in OEF/OIF
  - 23% of these veterans lost more than one limb.

Varma et al, Phys Med Rehabil Clin N Am 25 (2014) 1–8

Cancer

- < 2% of amputation discharges per year
- Most commonly involve the lower extremity
- Overall rates are decreasing
  - earlier detection
  - better adjuvant therapies and surgical limb salvage techniques

Graham et al, Arch Phys Med Rehabili Vol 89, March 2008

Congenital

- 26 per 100,000 live births
- Stable over last 30 years
- 58.5% involve UE
- most common = left transradial

Source: National Limb Loss Information Center

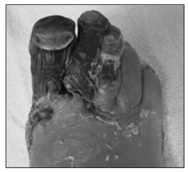
Amputation Level Selection

- Both biological factors AND functional factors must be taken into account
- Distal procedure generally provides better functional outcome
- more distal procedures may have a higher risk of non-healing and revision surgery
- multi-disciplinary team input is important pre-operatively

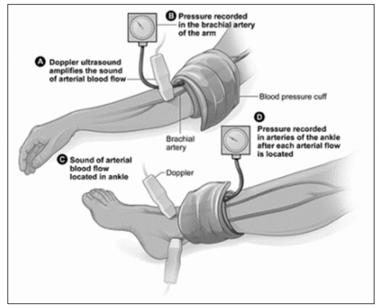
Biological Factors

- **Clinical exam :**
  - **Extent of wound or infection**
  - **Vascular Status**
    - **Palpable**
    - **Doppler**
    - **ABI**
  - **Sensation**
  - **ROM**
- **Skin Temp**
- **Tissue Quality**
- **Nutrition (Alb >3.0)**
- **TcPO2 (> 30)**

Vs.



Ankle Brachial Index (ABI)



- **systolic BP measured at ankle divided by the SBP measured at the brachial or radial artery**
- **pressure is normally higher in the ankle than in the arm**

ABI Interpretation

ABI Result	Interpretation	Recommendation
> 1.30	Non-compressible arteries	**Refer to Vascular Surgery**
1.0 – 1.3	Normal	None
0.9 – 1.0	Acceptable	
0.8 – 0.9	Mild PVD	Risk Factor Modification
0.5 – 0.8	Moderate PVD	**Refer to Vascular Surgery**
< 0.5	Severe PVD	

Toe Brachial Index (ABI)

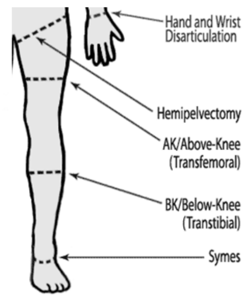
- **Generally performed if ABI > 1.3**
- **> 0.7 is normal**
- **< 0.7 abnormal**
- **< 0.3 potential for wound healing is poor**

Functional Factors

- Previous level of ambulation
- Cognitive skills
- Vision
- Motivation and patient goals
- Cardio-pulmonary status
- Presence of contractures
- Family support
- Depression/Psych Issues

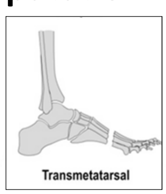
Types of Amputation

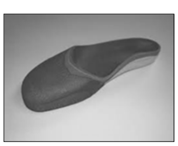
- Toe Amputations
- Ray Amputations
- Transmetatarsal Amputation
- LisFranc
- Chopart
- Symes
- Transtibial (below knee)
- Knee Disarticulation
- Transfemoral (above knee)
- Hip Disarticulation

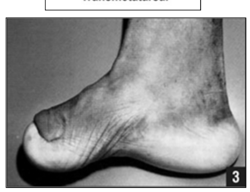


Transmetatarsal Amputation

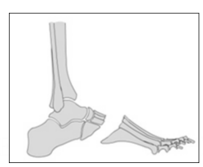
- appropriate when distal perfusion is good and adequate plantar tissue is available for well padded flap
- can generally walk without issue but may have pain with high impact activities



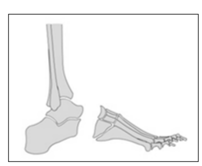




Midfoot Amputations



1. Lisfranc
   - amputation at the tarsometatarsal junction
   - similar to a very short TMA



2. Chopart
   - amputation at the talonavicular and calcanealcuboid joints
   - Often combined with :
     - Full achilles release
     - anterior tibialis tendon transfer to talus

Midfoot Amputations

- occasionally done in cases of foot trauma
- not great options for dysvascular patients due to poor healing
- both prone to equinovarus deformities

Syme's Amputation

- Ankle disarticulation
  - medial and lat malleoli shaved down
  - calcaneal heel pad retained to cover distal end of tib/fib
- Advantages
  - Better for infection
  - Longer lever arm
  - Can be use for limited weight bearing
- Disadvantages
  - Poor cosmesis
  - Difficult fit with prosthesis

Below Knee Amputation

- most common LE amputation
- goal is a cylindrical shape
- ideal length is controversial
- difficult lengths:
  - "too long" -> below the distal 2/5 of the tibia (below the gastroc-soleus muscle)
  - "too short" -> proximal to the tibial tubercle

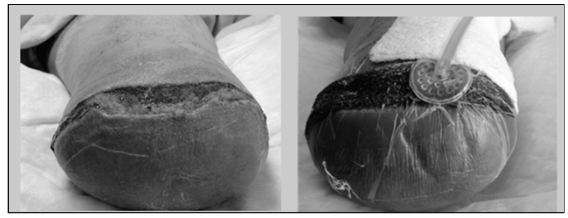
Knee Disarticulation

- Relatively uncommon
  - Utility debated
  - Done in trauma when knee joint is damaged
- Advantages
  - Decreased metabolic cost of ambulation compared with AKA
  - Distal end bearing provides proprioceptive feedback
- Disadvantages
  - Difficult to maintain comfortable prosthetic fit
  - Poor cosmesis

Above Knee Amputation

- considered when no other distal amputation is feasible from a tissue perspective
- Transection below the lesser trochanter, the limb tends to develop excessive flexion and abduction at the hip joint
- associated with an increased metabolic cost of ambulation
- can be associated with decreased functional outcome in certain patient populations

Complications Following Amputation



30 Day Mortality Rates

- 9000+ patients (all causes of amputation) from 2005-2010
- Compared to below knee amputees, above knee amputees:
  - 30 day mortality rate was almost doubled
  - Rate of complications was greater
- However, below-knee amputees were associated with:
  - Greater reoperation rate
  - Higher mortality great in BKAs who required a return to the OR

Nelson et al. Surgery 2012;152:685-696

30 Day Mortality Rates

- Factors associated with increased mortality:
  - Age > 80
  - Totally dependant functional status
  - Dialysis
  - steroid use
  - CHF
  - medical complications :
    - pre-op sepsis
    - delirium
    - thrombocytopenia
    - increased INR
    - azotemia

Nelson et al. Surgery 2012;152:685-696

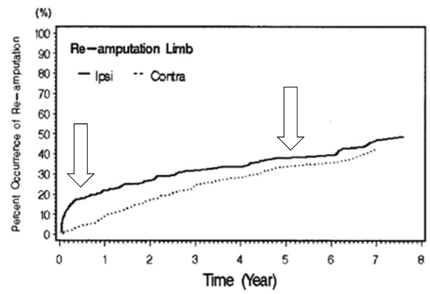
Dysvascular Amputees: Long Term Survival

	1 year Survival	5 year Survival
Overall	**69.7 %**	**34.7 %**
AKA	**50.6 %**	**22.5 %**
BKA	**74.5 %**	**37.8 %**
w/out diabetes	**70.8 %**	**51%**
With diabetes	**69.4 %**	**30.9 %**
w/out ESRD	**75.4 %**	**42.2 %**
With dialysis-dependent ESRD	**51.9 %**	**14.4 %**

reduced by 1/2 (AKA and BKA 5 year survival)

Aulivola et al. Arch Surg 2004;139:395-399

Dysvascular Amputees: Long Term Complications

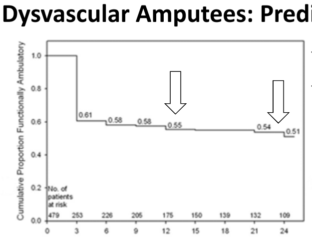


- **Patients are at greatest risk for ipsilateral re-amputation within the first 6 months of initial amputation**
- **Risk for amputation of the contralateral limb increases steadily over time**

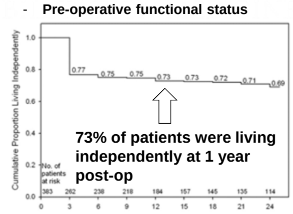
Izumii et al. Diabetes Care 2006;29:566-570

Functional Outcomes of Amputees

Dysvascular Amputees: Predicting Functional Outcomes



- **55% of patients were functionally ambulatory at 1 year post-op**
- **factors that predicted maintenance of ambulation:**
  - **Age < 50, gender (male>female)**
  - **Amputation level (BKA > TKA > AKA)**
  - **No CAD, ESRD or dementia**
  - **Pre-operative functional status**
- **factors that predicted failure of ambulation:**
  - **Age >70**
  - **Bilateral amputation**
  - **ESRD**
  - **household ambulator only pre-op**



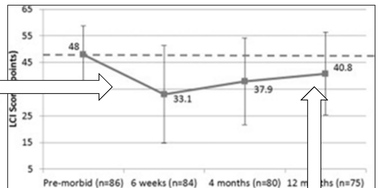
73% of patients were living independently at 1 year post-op

Taylor et al, J Vasc Surg. 2005, 42 (2), 227–234

Dysvascular Amputees: Functional Outcomes

- 75 patients undergoing first amputation
- Locomotor capability index used to assess level of ambulation at several time points

Ambulatory mobility declined during the period immediately prior to surgery (premorbid) and remained low at 6 weeks post-surgery



Ambulation improved after surgery, but did not return to premorbid levels.

- Mobility decline was 30% from premorbid levels in TF amputees, vs 12 % in TM and TT amputees
- Rate of ambulatory decline was steeper in patients who were older age and those who had a history of lower-extremity arterial reconstruction

Czerniecki et al. Arch Phys Med Rehabil. 2012 Oct;93(10):1766-73

Trauma Outcome: Salvage vs. Amputation

- LEAP study, NEJM 2002
  - 569 patients with LE injuries at 8 level 1 trauma centers
  - 2 year prospective observational study
  - 384 reconstructions vs. 161 amputations
- No socio-demographic differences in the groups
- Results -> No differences between groups in :
  - Sickness impact profile (SIP) at two years
  - Functional outcome
  - Return to work
- Conclusion
  - No significant difference in functional outcomes at two years
- F/U study of same patients at 7 years
  - Still no differences in outcome between groups

Bosse et al. N Engl J Med, Vol. 347, No. 24

Amputee Rehabilitation

1. Preprosthetic Phase
2. Prosthetic Training
   - Inpatient
   - Outpatient
3. Lifelong prosthetic care

Pre-prosthetic Phase

- Spans the time from POD#1 until patient is fitted for initial prosthesis
- Length of time is variable

Goals of Pre-prosthetic Phase

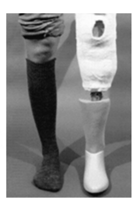
- Promote wound healing
- Prevent injury to surgical site
- Achieve sufficient mobility and ADL function to safely return home
- Prepare amputee physically for eventual prosthetic fitting
- Address psychological adjustment
- Address pain
  - Residual limb pain
  - Phantom limb pain

Post-Operative Dressing in the TTA

- Protects wound
  - Falls
  - Wheelchair
- Prevents contracture
  - Knee flexion
- Control edema
- Shapes limb
- Facilitate early weightbearing

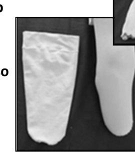
Types of Post-operative Dressings

1. Rigid dressings:
   a) thigh-high non-removable rigid plaster without or IPOP
      - Allows for early partial weigh-bearing
      - Can't inspect wound
   b) Short removable rigid plaster dressing
      - Good edema control and wound can be inspected
   c) Prefabricated removable plastic dressing (Flotech)
      - Mainly to position knee and prevent contractures but does also help to limit edema



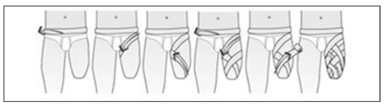
Types of Post-operative Dressings

2. Soft dressings:
   a) figure of 8 dressing (ACE wrap)
      - Tend to loosen throughout the day -> must be applied multiple times daily
   b) tubular compressive dressing (e.g. Tubigrip)
      - Easy for patients to pull on
      - Can vary amount of compression by layering
   c) Commercially made "stump shrinkers"
      - commonly used after staples/sutures have been taken out to help shape the residual limb in preparation for casting
   - Advantages: low cost, easy access to wound
   - Disadvantages: poorly applied elastic bandages also can cause circumferential constriction with distal edema, also don't protect from trauma or prevent knee flexion contractures



Post-Op Wound Care in TFA

- Soft dressing (rigid dressings aren't used)
- Edema control with proper application of elastic bandaging or a stump shrinker

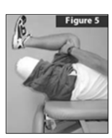


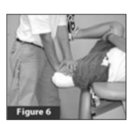
Pre-prosthetic Rehabilitation

- ROM and contracture prevention
- Strengthening
- Functional activities
- Balance
- General conditioning
- Cardiovascular endurance

Contracture Prevention

- Hip Flexion Contracture
  - Prone lying
    - Pillow or rolled towed under thigh
    - Avoid back extension
  - Supine stretching
- Knee Flex Contracture
  - Cast or flow tech
  - ROM exercises if not in cast
  - Knee extension board while in WC





Contracture Prevention

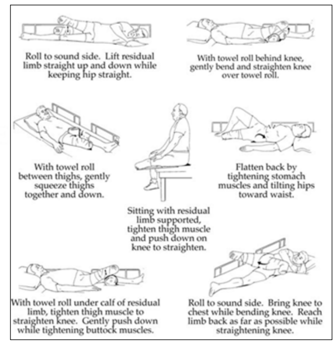
- Don't forget patient and family education! Usually needs reinforcement
- include nursing and other care staff in the education process
- role of the PM&R consult team -> include this in consult note recommendations

Pre-prosthetic Phase

- Massage of incision and peri-incisional skin helps to prevent adhesion of scar tissue
- "Handling" the residual limb helps desensitize tissue and prepare tissues for pressure associated with prosthetic wear

Pre-prosthetic Phase

- Strengthening
  - dynamic residual limb exercises
  - abdominal and back extensor strengthening
  - include exercises for intact limb and upper extremities



Pre-prosthetic Phase: Balance

- Amputee needs to learn to compensate for loss of amputated limb by balancing COM over intact limb
- Progress to unsupported standing balance

WWII Amputees Performing Balance Exercises, Stark General Hospital, Charleston, S.C. (Circa 1945)

Is your patient ready for a prosthetic?

- Is the surgical incision healed?
- Is the residual limb edema controlled (wearing stump shrinker)?
- Can the patient's cognitive status support prosthetic use?
- What is the patients current functional mobility?
  - Can patient transfer independently and hop up and down the parallel bars?
  - Are they pushing their MWC on their own?
- Sitting and standing balance
- Strength, ROM, coordination
- Patient motivation/goals
- Other factors
  - Vision, status of the other limb, compliance

Summary

- The most common cause of amputation (incidence) is due to dysvascular disease
- Amputation level should be determined by both biological and functional factors
- Lower extremity amputees have potentially poor functional outcomes -> cohesive rehabilitation planning is crucial
- Preprosthetic phase of the amputee care must :
  - promote limb healing
  - prevent contractures
  - prepare the patient physically and mentally for prosthetic fitting

Component Selection in Lower Extremity Prosthetics

Molly McCoy, L/C.P.O.
McCoy Consulting, LLC

The “real” question!

How do we design a prosthesis that can optimize mobility in individuals with lower extremity amputations?

Patient Factors Influencing Prosthetic Design Choices

- Global Health Status (Activity level & Medicare K-levels)
- Cognitive Status (Complex vs Simple interventions)
- Stage of Recovery (Progressing / Stable / Regressing)
- Balance and Global Strength (Falls)
- Specific Strength and ROM (Knee Hip and Sound Side)
- Goals (Activity expectations & Psychosocial health)
- Residual Limb Characteristics (Length, Skin Integrity, and Soft Tissue Volume)
- Protective Sensation / Pain
- Cost, Durability, Climate, Pt Preference

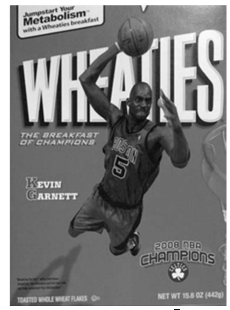
Clinical Trends Influencing Prosthetic Design

- Old vs New Ideas
- Continued development of products
- Clinician preference (familiarity vs bias?)
- Reimbursement for services
- Limited number of comparative effectiveness trials

Outline

- Socket Design
- Socket Interface
- Suspension
- Feet
- Knees

Socket Design



The Magic is in the Socket!

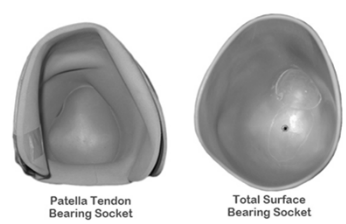
TT Socket Goals

- Connect residual limb to foot
- Eliminate "pseudoarthrosis" between socket and prosthesis.
- Comfortable transfer of forces and loads

Early Socket Design

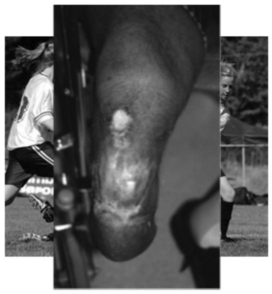
PTB

- Revolutionary socket design in '50s
- Incorporates specific regions of weight bearing and relief



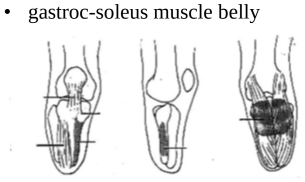
TT Socket Design Challenges

- Tibial crest vulnerable
- End of residual limb intolerant to weight bearing
- Fibular head
- Tibial tubercle



PTB Weight Bearing Areas

- patella tendon
- medial tibial flare
- pretibial musculature
- popliteal area
- fibular shaft
- gastroc-soleus muscle belly



Variations on PTB Socket Design

PTB-SC (Supracondylar)

Incorporates femoral condyles

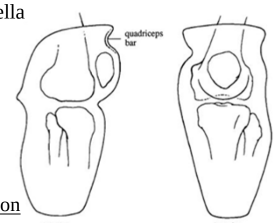
- Suspension
- Controls for mild m/l instability
- Poor sitting cosmesis
- Good for short RL

Variations on PTB Socket Design

PTB-SCSP (Supracondylar Suprapatellar)

Incorporates femoral condyles and patella

- Suspension
- Controls for mild m/l instability
- Poor sitting cosmesis
- Good for short RL
- Controls for mild knee hyper-extension



PTB Socket Design

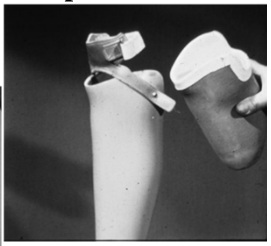
Possible Indications

- Specific areas not pressure tolerant
- Simplicity (less cognitively complex due to suspension)
- Low cost needs
- Low maintenance
- Short limbs (PTB-SCSP)

Disadvantages

- Possibly less accommodating to daily volume fluctuations
- Best with intact sensation
- Limited suspension and socket interface options

Early TT Suspension Methods

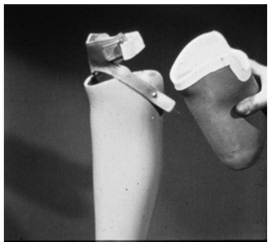


TT Suspension Methods

Cuff Strap Suspension

- **Very Simple**
- Very Low Cost
- Durable

- **Allows pistoning**
- Contraindicated in pt's with excessive soft tissue
- Can constrict blood flow



TT Suspension Methods

Knee Sleeve Suspension (Neoprene)

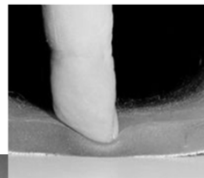
- Simple
- Cosmetic ?
- Low cost
- Reduces pistoning when compared to a cuff strap

- **Significant UE strength and dexterity required**
- Low durability
- Reduced sitting comfort

Hydrostatic Socket Design

Total Surface Bearing/Hydrostatic

- *Even* distribution of pressure
- **Gel liner *flows* away from high pressure and self relieves**
- Subtle socket contours
- Requires a tighter socket fit
- Volume dependent
- Special casting method
  - CAD
  - Pressure
  - Vacuum casting



Hydrostatic Socket Design

Possible Indications

- Lack protective sensation
- Poorly vascularized skin
- Problems over PTB wt. bearing areas
- High activity pt
- Skin grafts / burns

Disadvantages

- Can be more challenging to donn
- Higher Cost
- Increased *hassle factor*
- Good hygiene required

Hydrostatic Capture Methods

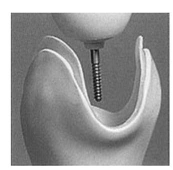
TT Suspension Methods

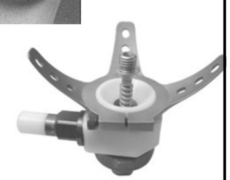
Pin lock suspension

Mechanical attachment via steel pin and locking mechanism

- Very secure suspension
- Minimal pistoning
- Socks can be added for volume loss

- **Challenging to align pin**
- Improper donning can cause distal limb trauma
- Distal distraction can cause pain





TT Suspension Methods

Seal-in liner

Use of membrane to create seal with auto air expulsion valve

- Sock can be added above membrane
- Eliminates distal distraction / pain

- Greater strength required to remove prosthesis
- Decreased volume accommodation capacity

TT Suspension Methods

Vacuum Pump

Active vacuum

Uses Rechargeable battery

Worn with sealing knee sleeve

User adjusted vacuum setting

-No perceptible socket limb motion

-Vacuum can cause skin breakdown

-Sealing sleeve can limit knee ROM

TT Suspension Methods

Pin / Sealing Liner/ Vacuum

- Minimal pistoning
- Decreased shear
- Increased stability

- Increased cost
- Washed daily
- Limited durability
- Complex wear and care protocol

TT Socket & Suspension Summary

PTB PTB-SC PTB-SCSP Hydrostatic

Vacuum Locking liner Sealing liner

Quality of skin

Length of limb

Knee stability

Soft tissue coverage

Stage of rehabilitation

Activity level

Protective sensation

Personal hygiene

UE dexterity and strength

Visual acuity

Goals

Cognitive function

Prior prosthetic history

TT Socket & Suspension Question

78 yo male TT amputation due to PVD, 2 months post-op, early Alzheimer's. Spouse assists with ADLs. Poor balance. Long residual limb. Global UE and LE weakness. Family goals are to use prosthesis for limited household ambulation and transfers.

A) PTB socket, neoprene sleeve suspension
B) PTB socket, cuff strap suspension
C) Hydrostatic socket, locking gel liner
D) Hydrostatic socket, Seal-in silicone liner

57 yo male with left transtibial amputation at age 12 secondary to trauma. UE and LE ROM and Strength WNL. Amputation of index and middle finger at MCP joint on R hand. Professional dancer, very active. No cognitive issues. Overall health status is excellent. Residual limb is 6" from MTP, protective sensation is intact, and the anterior distial tibia is very prominent. Private pay, with resources to cover costs.

A PTB socket, neoprene sleeve suspension
B PTB socket, cuff strap suspension
C Hydrostatic socket, locking gel liner
D Hydrostatic socket, gel liner, vacuum suspension

TF Socket Design Goals

- Transfer motion of Femur
- Stabilize mechanical knee
- Provide comfortable distribution of forces
- Allow pelvic stabilization

TF Quadrilateral Socket

- Ischial tuberosity sits directly on a “seat”
- Gluteal musculature weight bearing on brim
- Compression of limb on socket walls in square shape

TF Quadrilateral Socket Indications

- Patient Preference
- Proven design criteria since 1950’s
- Ease of troubleshooting
- Pt must be able to tolerate high proximal medial pressure

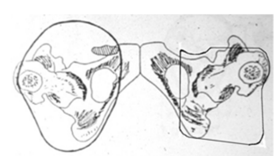
TF Ischial Containment Socket

- Anatomical shape
- Ischial tuberosity inside of socket
- Improved function of Gluteus Medius

TF Socket Design Summary IC vs Quad

Consider

- Pt’s prosthetic HX
- Activity level
- Hip strength
- Limb length



TF Suspension Methods

- Suction Suspension
- Pin / Shuttle lock suspension
- Waist Belt Suspension
- Hip Joint and Pelvic Band

TF Suspension Methods

Suction

- Eliminates Pistoning
- "Proprioceptive" Feedback
- Requires stable limb volume
- Difficult to donn
- Works best with longer limbs

TF Suspension Methods

Suction

- Eliminates Pistoning
- "Proprioceptive" Feedback
- Requires stable limb volume
- Difficult to donn
- Works best with longer limbs

TF Suspension Methods

Pin Suspension

- Rarely need to protect boney prominence
- Push-in vs Pull-in
- Minimal pistoning
- Less difficult than suction to donn
- Can accommodate for volume loss
- Works well with short limbs
- Good hygiene required

TF Suspension Methods

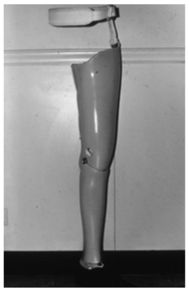
Silesian Belt Suspension

- Simple & Inexpensive
- Easy to donn
- Accommodates volume change / socks
- Allows pistoning
- Works best on thin patients
- Good Secondary suspension

TF Suspension Methods

Hip Joint & Pelvic Band

- Maximum coronal stability
  - Very Short Limb
  - Weak Abductors
- Simple
- Poor sitting comfort
- Allows pistoning
- Limits hip ROM
- Bulky



TF Suspension Summary

Suction Pin Belt Hip-Joint

Consider
- Balance
- UE Strength and dexterity
- Hygiene
- Cognition
- Stage of rehab
- Soft tissue
- Hip strength
- Visual acuity

TF Suspension Questions

23 yo male, s/p R TF amputation 2° to MVA 3 years ago, long residual limb without scaring, no other complicating injuries, global health is excellent

A Locking liner

B Suction

C Silesian belt

D Hip joint and pelvic band

Prosthetic Knees

- Passive hinge
- Knee stability maintained
  - Closed chain hip extension
  - COM anterior to knee axis
  - Firmness of heel

Prosthetic Knees

CMS funding based on activity level

- K Level 1: Patient has the ability or potential to use a prosthesis for transfers or **ambulation on level surfaces** at a **fixed cadence**; typical of the limited and unlimited **household ambulator**.
- K Level 2: Patient has the ability or potential for ambulation with the ability to transverse low-level environmental barriers such as **curbs, stairs or uneven surfaces**; typical of the **limited community ambulator**.
- K Level 3: Patient has the ability or potential for ambulation with **variable cadence**; typical of the community ambulator who has the ability to **transverse most environmental barriers** and may have vocational, therapeutic or exercise activity that demands prosthetic utilization beyond simple locomotion.
- K Level 4: Patient has the ability or potential for prosthetic ambulation that **exceeds basic ambulation skills**, exhibiting high impact, stress or energy levels; typical of the prosthetic demands of the **child, active adult or athlete**.

Prosthetic Knees

Single Axis Constant Friction

- Single speed walking
- Strong hip extensors
- Low Maintenance
- Low Cost
- Appropriate patient?
- K?

Prosthetic Knees

TF Polycentric Knees

- Axis of rotation proximal and posterior
- Increased stability
- Single speed or variable cadence
- K1-3

Prosthetic Knees

Manual Locking

- Need for maximum stability
- Creates significant gait deviations
- Knee of last resort
- Pt progressed to unlocked knee?

Prosthetic Knees

Fluid Controlled

- Variable cadence
- Inherent stability
- Option for stance yielding
- Expensive
- Heavy
- K3 - K4

Prosthetic Knees

Microprocessor Controlled

- Fluid Controlled Knee
- Microprocessor
  - Adjusts swing resistance
  - Switches from stance to swing
- Decrease falls
- Descent of stairs improved
- Hill descent time improved
- Improved patient satisfaction
- Increased wear time
- Decreased mental load
- Expensive $17,000-20,000

Power Knee

- Active knee motion during swing and stance
- Weight 7 lb.
- Battery life about 6 hrs
- Cost to prosthetist $30K
- Noise

Prosthetic Knees Summary

Consider
- Stability needs
- Balance
- Hip strength
- Limb length
- Patient goals
- Activity level
- Terrain
- Insurance coverage / maintenance needs

Knee Question

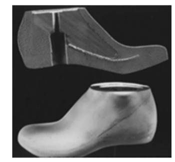
58 yo male R TK, elective amp 15 yrs ago, polio as child. K3 ambulator, reports frequent falls. R Hip extensors 3/5, flexors 4/5.
Retired Boeing engineer. Very active, lives on a small farm, cares for livestock.
Goals to reduce falls and maintain high activity level, currently using a polycentric knee.

A Single Axis
B Manual locking
C Polycentric knee
D Micro-processor hydraulic

Prosthetic Feet


- Stable standing platform
- Absorb ambulatory forces
- Decrease moments at knee
- Store and release energy
- CMS bases funding on K-level
- Cost range from $200 - $6,000

Prosthetic Feet



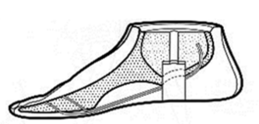
SACH

- Solid Ankle Cushion Heel
- Simple & Inexpensive
- Foam heel and wood keel
- Lacks structural flexibility
- Not very durable
- Low activity use
- K1

Prosthetic Feet

Elastic Keel

- Smooth transition through gait cycle
- Foam heel and elastomeric keel
- Inexpensive
- K2 Limited community ambulator



Prosthetic Feet

Single Axis

- Most common for TF
- Decreased flexion moment at knee
- Heavy
- Increased maintenance
- K1-K2

Prosthetic Feet

Multi Axis

- Accommodation to uneven ground
- Decreased forces translated to socket
- Increased weight & maintenance
- Slightly increased cost
- K2-K3

Prosthetic Feet

Dynamic Response (Energy Storing)

- Light weight
- Low maintenance
- Decrease Energy
- Potential High Cost
- K3-K4

Prosthetic Feet

- A Word About Powered Ankles

Prosthetic Feet

Consider

- Activity level or potential
- Terrain
- Hip and / or knee strength
- Durability needs
- Cost

The Winkley Leg is the Monarch of the Industry

Large Heavy Men Are Also Successfully Fitted With Winkley Patent Adjustable Double Slip Socket Legs

This Oklahoma Merchant wrote: "I weigh 252 pounds and am upon my feet almost continuously and able to lift and carry a couple hundred pounds while wearing my Double Slip Socket Leg."

This man was so large and heavy that he never expected to be able to wear a leg. He weighed 305 pounds and measured 60 inches around the waist. He put on his Winkley Patent Adjustable Double Slip Socket Leg and walked right off with it and wore it every day with ease and comfort.

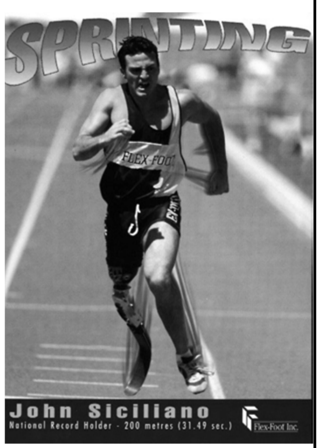
Prosthetic Feet Question?

68 yo male PVD, short TF, 5 week post amputation. Poor strength and balance global 4/5. Currently can hop 10' with wheeled walker on level surface. Ambulated prior to amputation with a single point cane. No cognitive compromise. Goal is to return to limited community ambulation.

A SACH
B Elastic Keel
C Single Axis
D Dynamic Response

Summary

- General physical well being
- Family Support
- Motivation
- Socket Fit
- Training
- Components



Molly McCoy, L/CPO

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- 678-997-1029

Prosthetic Alignment in the Transtibial Amputee

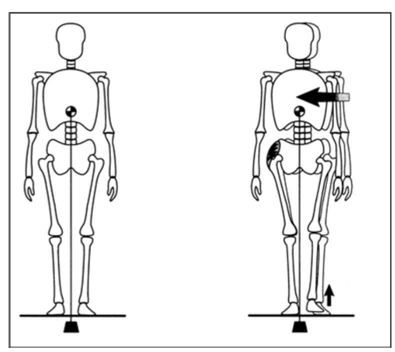
David C. Morgenroth, MD,
Department of Rehabilitation Medicine
University of Washington
VAPSHCS

The Starting Point

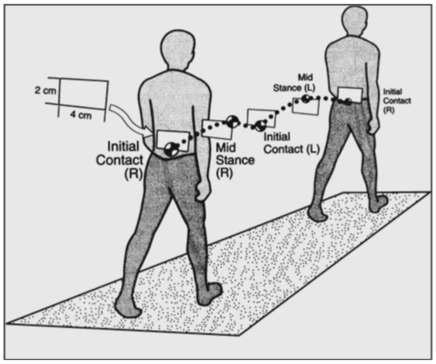
Outline

- Normal gait review
- Coronal plane alignment
- Sagittal plane alignment

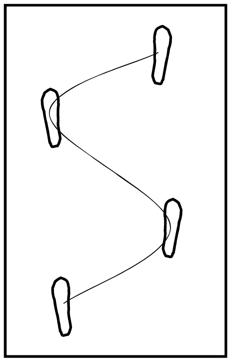
COM Motion in the Coronal Plane



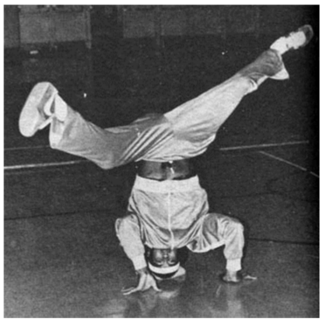
Coronal Plane COM Motion



Normal Medial Lateral Excursion of the COM



Moment (Torque)



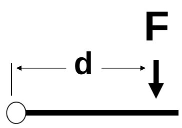
Joint Moments (Torques)

Moment of Force

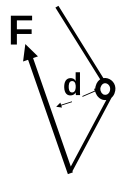
- **Force that tends to cause rotation of a rigid body in space.**
- **Determined by the product of the magnitude of the force and the distance from the center of rotation.**

$$\mathbf{M = F \times d}$$

Joint Moments



Single Rigid Segment



Two Segments Linked at a Joint

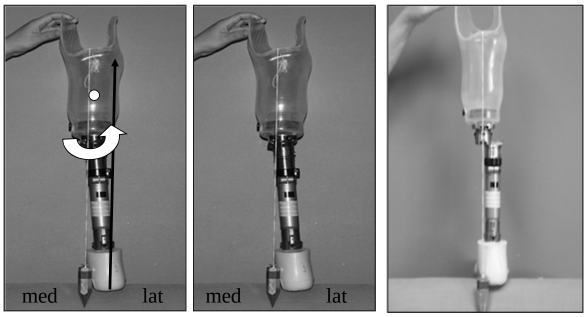
External versus internal joint moments

Prosthetic Coronal Plane Alignment Variations

Normal Coronal Plane Bench Alignment

Normal

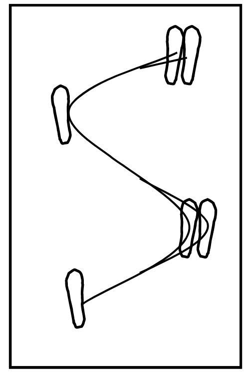
The Laterally Displaced Foot



Valgus Outset

Laterally Displaced Foot

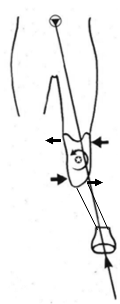
- ?Mechanism to shift COM laterally
- Increased lateral trunk shift
- ?Effect on efficiency



Effect on Socket Pressure Distribution

Increased socket pressure
- proximal lateral
- distal medial

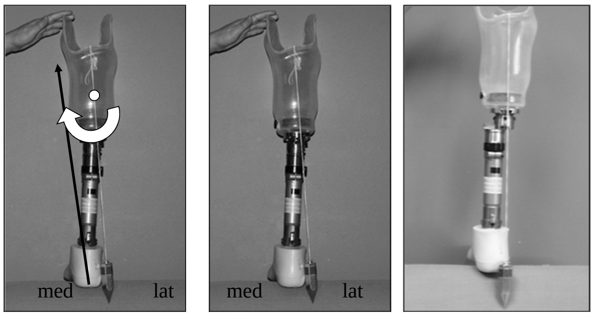
Reduced socket pressure
- proximal medial (medial thrust)
- distal lateral



Gait Characteristics of a Laterally Placed Foot

- Increased width of base of support.
- Medial thrust at the proximal socket brim during prosthetic stance phase.
- Increased lateral trunk motion to the prosthetic side during prosthetic stance.

The Medially Displaced Foot

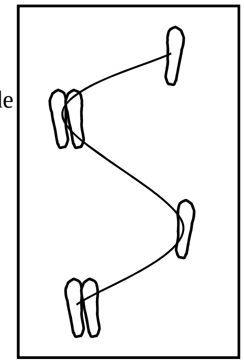


Varus Inset

Medially Displaced Foot

- Path of COM is lateral to foot

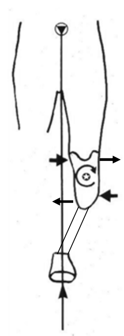
- Loss of balance to the prosthetic side



The Medially Displaced Foot

Increased socket pressure
- proximal medial
- distal lateral

Decreased socket pressure
- proximal lateral (lateral thrust)
- distal medial



Gait Characteristics of the Medially Placed Foot

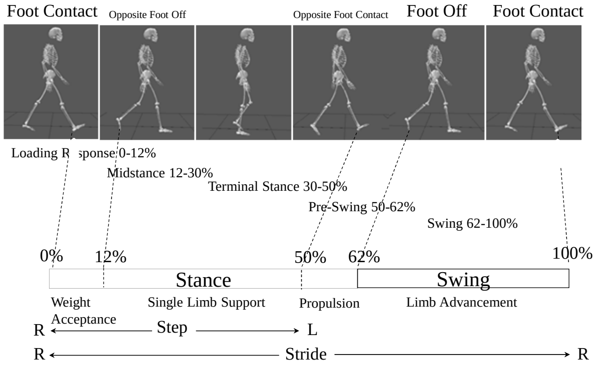
- Narrowed base of support.
- Lateral thrust at the proximal socket brim during prosthetic stance phase.
- Possible loss of balance to the prosthetic side during prosthetic stance phase.

Leg-length discrepancy

-Static versus dynamic
-What do you see on gait analysis?
-What problems do LLD cause?

Sagittal Plane Kinetics and Kinematics

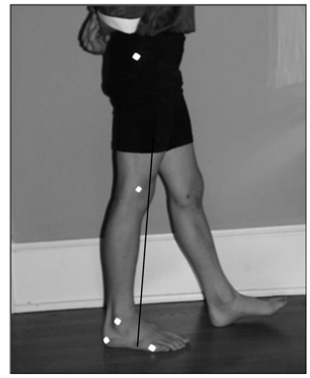
The Gait Cycle



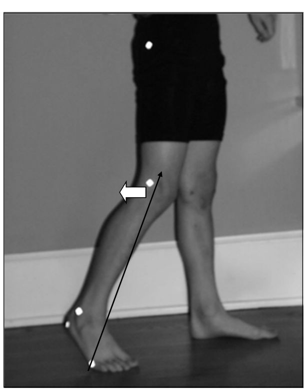
Heel Contact

Foot Flat/Loading Response

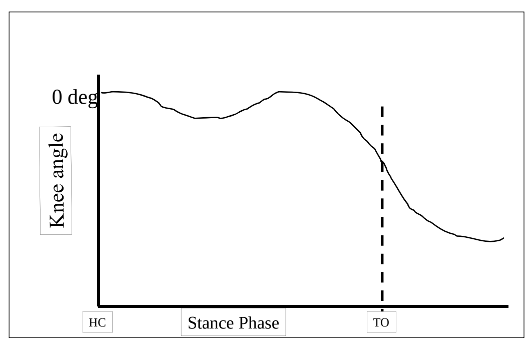
Mid Stance Phase



Terminal stance into pre-swing

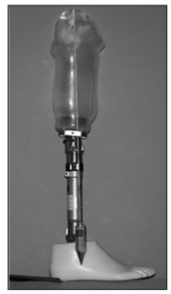


Knee Kinematics during Stance



Prosthetic Sagittal Plane Alignment Variations

Saggital Plane Translations of the Prosthetic Socket



Normal

Posterior Pylon

Anterior Pylon

Saggital Plane Angulations Excessive Socket Flexion/Extension

Normal

Flexion

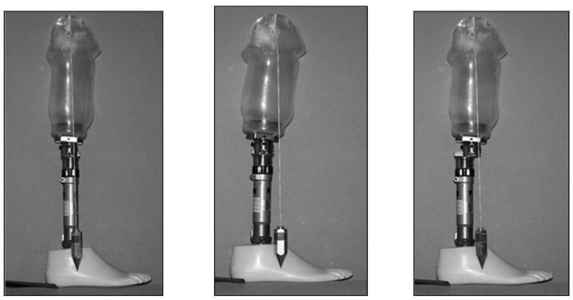
Extension

The Effect of Heel Height

Heel too high

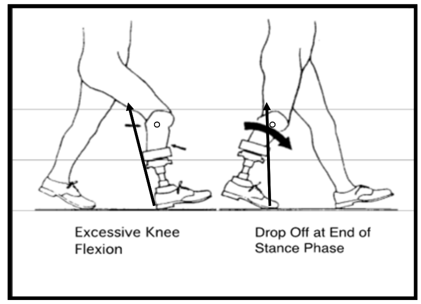
Heel too low

Saggital Plane Malalignments
↑ Heel Lever ↓ Toe Lever



Normal　　Flexion　　Posterior Pylon

Increased Knee Flexion Moment / Decreased Knee Extension Moment



Where do you expect to see skin breakdown?

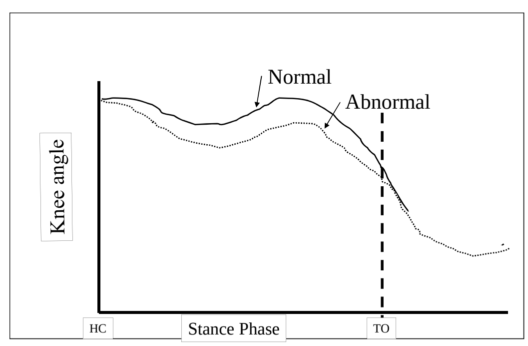
Increased Heel Lever / Decreased Toe Lever

Heel too high, Increased socket flexion, Anterior translation of socket

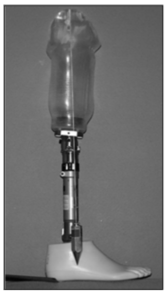
- Rapid excessive knee flexion at heel contact through early and mid stance.
- Drop off continued excessive knee flexion in late stance
- Rapid swing phase of contralateral limb.

Knee Flexion Angle in Stance Phase

Increased heel lever / Reduced Toe Lever



Sagittal Plane Malalignments
↓ Heel Lever ↑ Toe Lever

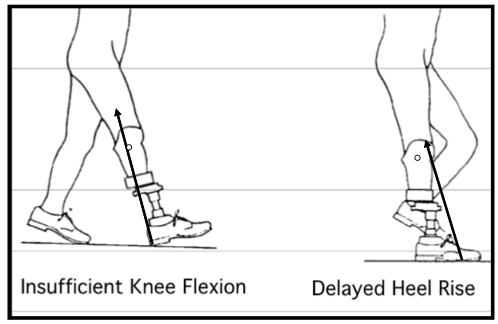


Normal

Anterior Pylon

Extension

↓Knee Flexion Moment / ↑Knee Extension Moment



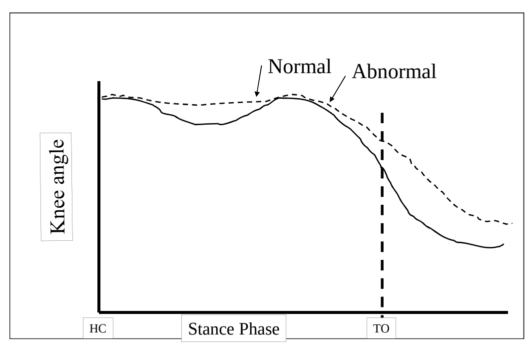
Reduced Heel Lever/ Increased Toe Lever

Heel too low, Decreased socket flexion, Posterior socket translation

- Reduced knee flexion in early stance.
- Difficulty progressing COM over stance phase foot.
- Shortened intact limb step length.

Knee Flexion Angle in Stance Phase

Reduced Heel Lever / Increased Toe Lever



The effect of prosthetic foot characteristics on sagittal plan alignment

Summary(1)

- Observe from the side (Sagittal plane alignment).
- Observe from behind (Coronal plane alignment).
- The “knee tells all”, with a few clues from the motion of the trunk and step kinematics.

Summary (2)

- Prosthetic alignment when optimized can substantially improve gait characteristics.
- A knowledge of prosthetic alignment can help us understand and treat residual limb pain problems.
- Evidence supports the benefits of optimum alignment on biomechanics of gait and metabolic energy expenditure.

Questions?

Upper Extremity Amputee Rehabilitation and Prosthetics

Jeffrey Heckman, DO
Medical Director
Regional Amputation Center
VA Puget Sound Health Care System
Seattle, WA

Outline

- Epidemiology
- Cause
- Levels
- Evaluation & Management
- Rehabilitation Program
- Prosthetic Systems
- Questions

Epidemiology

- “Prevalence” is determined by the number of people living with amputations and looks at how many people are affected
- “Incidence” refers to the number of new cases, usually per year, per population at risk.

Prevalence

- There are 1.2 to 1.9 million people in the United States living with limb loss, excluding finger tip and toe amputations
- One in every 200 people in the U.S.

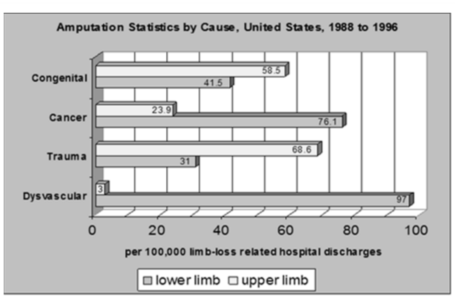
Incidence

- Limb Loss Research and Statistics Program, 2008:
  - 185,000 Americans undergo amputation each year.
- Dillingham, 2002:
  - 1,199,111 hospital discharges that involved amputation or congenital limb deficiency from 1988 through 1996
  - 133,235 amputations per year
  - 1996 annual rate of 52 amputations per 100,000 US population.
    - Upper limb amputation incidence rate was 5/100,000
    - Lower limb amputation incidence rate was 47/100,000

Causes

- Trauma
- Congenital
  - deformities - dysmelia
  - shortened limb – phocomelia
  - absence of upper limb – amelia
- Cancer
  - tumors – osteogenic sarcoma, ewing's sarcoma
- Disease related - Dysvascular
  - Emboli from meningococcemia may cause auto-amputation of limbs or digits and can affect all 4 limbs

Causes



Causes- By Age

- Birth-15 years old:
  - Most common: Congenital disorders
- 15 – 45 years old:
  - Most common: Trauma
- 70% of Upper Limb Amputation occurs in individuals younger than 64 years old
- Large number of individuals leading very active lives with upper limb amputation

Congenital Upper Limb Deficiency

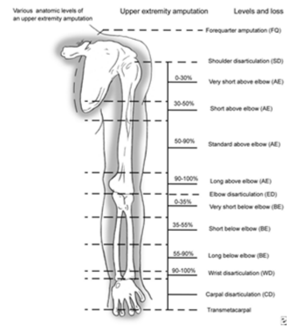
- 4.1 / 10,000 live births
- Most cases have no hereditary implications
- Craniofacial anomalies are associated with limb deficiencies

  5 associated conditions:

  1. TAR syndrome: thrombocytopenia with absence of radius
  2. Fanconi's Syndrome: anemia, leukopenia
  3. Holt-Oram Syndrome: congenital heart disease
  4. Baller-Gerold Syndrome: craniosynostosis
  5. VACTERL: Vertebral defects, Anal atresia, Cardiac defects, Tracheoesophageal fistula, Renal dysplasia, Limb Deficiency

Levels- ISPO Classification

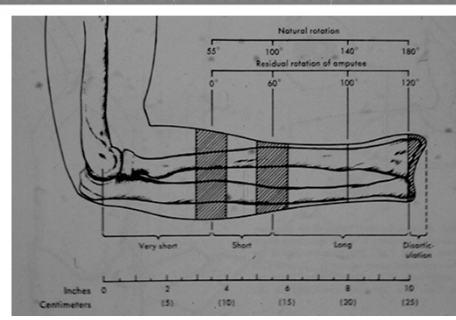
- Digit Amputation
- Partial Hand
- Wrist disarticulation
- Transradial (57%)
- Elbow disarticulation
- Transhumeral (23%)
- Shoulder disarticulation
- Forequarter



Wrist Disarticulation Amputation

- Advantages:
  - Maximum Pronation/Supination
  - Maximum leverage for lift/push
- Disadvantages:
  - Bulky distal end
  - Poor prosthetic cosmesis
  - Need 3-4 cm for wrist unit

Degrees of Pronation



Trans-radial Amputation

- Long = 55-90 % of radius intact
  - Ideal length for function and cosmesis
  - Maintains most of pron/sup and leverage
- Short = 35-55 % of radius intact
  - Still very functional and fittable
- Very short = 0-35 % of radius
  - Difficult socket fit and limited function

Elbow Disarticulation Amputation

- Advantages:
  - Maximum leverage for lift/push
  - Humeral condyles assist with suspension
- Disadvantages:
  - Bulky distal end
  - Poor prosthetic cosmesis
  - Must use external elbow joints
  - Need 4-5 cm for electric elbow

Trans-humeral Amputation

- Long = 50-90 % of humerus intact
  - Ideal length for function and cosmesis
- Short = 30-50 % of humerus intact
  - Limited leverage for lift/push
  - Socket design now limits shoulder motion
- Very short = Humeral neck = 0-30 % intact
  - Fit as shoulder disarticulation

Shoulder Disarticulation Amputation

- Difficult socket design
- Difficult to achieve functional prehension
- Heavy prosthesis may not be tolerated
- Patient may choose to be independent without prosthesis if other hand intact

Forequarter Amputation

- Loss of entire limb and scapula
- Most commonly caused by tumor resection
- Lightweight cosmetic prosthesis is the most practical device

Bilateral Upper Limb Amputation

- Fit the longer residual limb with a prosthetic device for functional prehension (pinch and gross grasp)
- Fit the remaining limb as an assist for longer limb
- Use any and all available assistive devices to achieve independence in self-care and ADL's

Evaluation of the Patient

Detailed History:

- Cause of amputation
- Hospital course, time frame
- Repeated surgical procedure
- Skin grafts, muscle flaps
- Nerve injury (brachial plexus, peripheral nerve)
- Other injuries (ortho, spine, brain)

Evaluation of the Patient

Pain History:

- Pain prior to amputation
- Pain related to surgery/procedures
- Phantom sensations
- Phantom pain
- Pain management

Evaluation of the Patient

Social History:
- Social support system and involvement
- Work history
  - Contact/Discussions with employer
- Patient concerns about family, friends, employer
- Financial issues
- Education level

Evaluation of the Patient

Psychological History:
- Prior psychological issues (depression, previous disabilities, high risk-takers)
- Current feelings about amputation
- Future concerns about function
- Body image issues
- Concepts about prosthesis
- Previous experience with prosthesis

Evaluation of the Patient

Avocational Activities History:
- Family Responsibilities
- Sports / Fitness
- Intimacy / Sex
- Driving
- Outdoor activities (swimming)
- Hobbies

Evaluation of the Patient

Physical Exam:
- Single limb vs. Multiple limb involvement
- Dominant vs. Non-Dominant limb loss
- Single limb loss – Examine remaining limb first in detail proximal and distal
- Check spinal alignment

Evaluation of the Patient

Physical Exam of the involved limb:

- Level of amputation, bone length
- Residual limb circumference
- Skin and soft tissue integrity
- Skin grafting or scarring, Adherent skin
- Tenderness to palpation
- Sensation throughout

Evaluation of the Patient

Physical Exam of the involved limb:

- Shoulder girdle muscles: (trapezius, rhomboids, pectoralis, serratus anterior, latissimus dorsi, supraspinatus, infraspinatus, subscapularis, deltoid)
- Shoulder A/PROM: glenohumeral joint (flexion/extension, abd/adduction, int/ext rotation) scapulo-thoracic rotation and stability
- Cervical spine mobility

Evaluation of the Patient

Physical Exam of the involved limb:

- Strength testing at elbow, wrist
- A/PROM testing at elbow, wrist
- Any remaining segments of hand

Management

Understand differences b/w UE and LE limb loss

- Fewer peers
- Less prosthetic fabrication experience
- Many fewer experienced therapists
- Multiple choices of prosthetic components and operating systems with large variation in cost
- Easier to function with remaining limb

Management

Education – Pre-prosthesis training program:

- Need for early therapy to mobilize joints and maintain strength
- Regain independence in self-care and mobility
- Residual limb shaping and shrinking
- Pain control
- Psychological issues
- Peer support

Management

Pre-prosthesis training program:

- Limb shaping with figure 8 ace wrap/shrinker
- Wound care and healing issues
- Strengthening of residual limb muscles for potential myoelectric control
- Strengthening of proximal muscles for potential body powered control
- ROM exercises at wrist, elbow, shoulder

Management

Education – Prosthesis:

- Discuss fitting/fabricating prosthesis and component selection
- Discuss prosthesis timeline
- Explain cosmetic vs. functional issues
- Inquire about insurance coverage for prosthesis
- Clarify patient concerns or misconceptions about prosthesis

Management

Prosthesis training program:

- Independent with ADLs using adaptive equipment
- Desensitizing techniques for residual limb
- Scar management
- Pain control
- Return locus of control

Management

Long term Management:

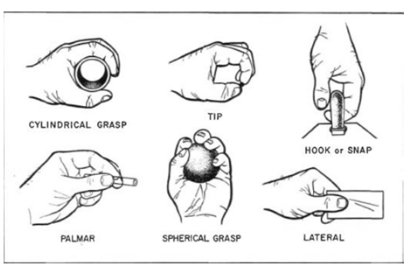
- Lifetime comprehensive management by amputee clinic team
- Skin tolerance issues
- Return to driving
- Return to work/school
- Return to avocational activities and sports

Prosthetic Systems

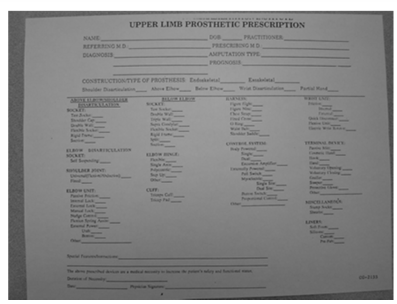
Why are we ordering a prosthesis?

- Prehension
- Movement
- Symmetry
- Balance
- Cosmesis

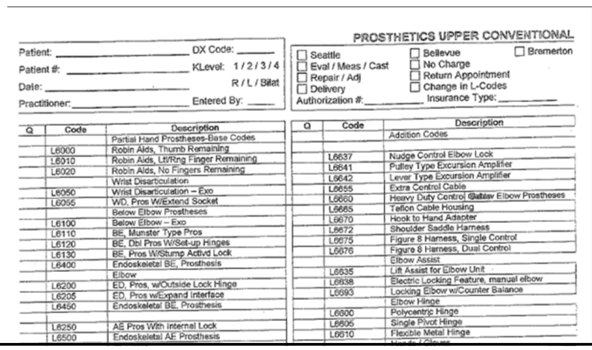
Prehension



Upper Extremity Prosthesis Rx


UPPER LIMB PROSTHETIC PRESCRIPTION

Upper Extremity Prosthetics: Order Form



PROSTHETICS UPPER CONVENTIONAL

Patient: ____________ DX Code: ______
Patient #: ____________ KLevel: 1 / 2 / 3 / 4
Date: ____________ R / L / Bilat
Practitioner: ____________ Entered By: ______

☐ Seattle ☐ Bellevue ☐ Bremerton
☐ Eval / Meas / Cast ☐ No Charge
☐ Repair / Adj ☐ Return Appointment
☐ Delivery ☐ Change in L-Codes
Authorization #: ________ Insurance Type: ________

Q	Code	Description
		Partial Hand Prostheses-Base Codes
	L6000	Robin Aids, Thumb Remaining
	L6010	Robin Aids, Ltl/Rng Finger Remaining
	L6020	Robin Aids, No Fingers Remaining
		Wrist Disarticulation
	L6050	Wrist Disarticulation – Exo
	L6055	WD, Pros W/Extend Socket
		Below Elbow Prostheses
	L6100	Below Elbow – Exo
	L6110	BE, Munster Type Pros
	L6120	BE, Dbl Pros W/Set-up Hinges
	L6130	BE, Pros W/Stump Activd Lock
	L6400	Endoskeletal BE, Prosthesis
		Elbow
	L6200	ED, Pros, w/Outside Lock Hinge
	L6205	ED, Pros w/Expand Interface
	L6450	Endoskeletal BE, Prosthesis
	L6250	AE Pros With Internal Lock
	L6500	Endoskeletal AE Prosthesis

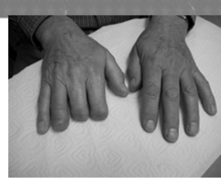
Q	Code	Description
		Addition Codes
	L6637	Nudge Control Elbow Lock
	L6641	Pulley Type Excursion Amplifier
	L6642	Lever Type Excursion Amplifier
	L6655	Extra Control Cable
	L6660	Heavy Duty Control Cable Above Elbow Prostheses
	L6665	Teflon Cable Housing
	L6670	Hook to Hand Adapter
	L6672	Shoulder Saddle Harness
	L6675	Figure 8 Harness, Single Control
	L6676	Figure 8 Harness, Dual Control
		Elbow Assist
	L6635	Lift Assist for Elbow Unit
	L6638	Electric Locking Feature, manual elbow
	L6693	Locking Elbow w/Counter Balance
		Elbow Hinge
	L6600	Polycentric Hinge
	L6605	Single Pivot Hinge
	L6610	Flexible Metal Hinge

Control Options

- Passive prosthesis
  - Cosmetic, allows passive positioning of joints or TD
- Body powered prosthesis
  - Uses proximal body movements to position joints/TD
- Myoelectric prosthesis
  - Uses surface electrodes to detect voluntary muscle activity in residual limb to activate joints/TD
- External powered prosthesis
  - Uses switch control to position joints/TD

Passive Prosthesis

- Multiple Digit Amputations



- Custom Silicone Finger Prostheses

Passive Prosthesis

- Transradial Limb Deficiency

- Custom Silicone Hand Prosthesis

Body powered prosthesis

- Advantages
  - Lighter weight
  - Less expensive
  - More durable
  - Better feedback
- Disadvantages
  - Harnessing required
  - Less cosmetic

Suspension Systems

- Figure 8 Harness
- Figure 9 Harness
- Shoulder saddle with chest strap
- Self suspension
  – Northwestern University socket design
  – Muenster socket design

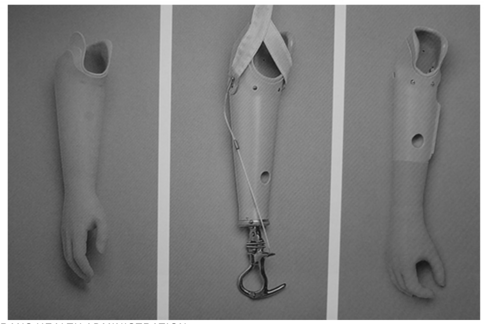
Figure-8 Harness

Figure-9 Harness

Harness (Figure 9)

Shoulder Saddle with chest strap

Self Suspension

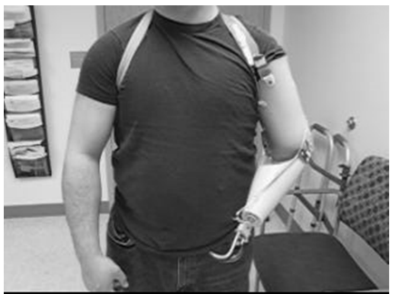


Body powered prosthesis

- Transradial Level
  - Body movement to operate TD
    - Forward humeral flexion
    - Bi-scapular abduction (protraction)
- Transhumeral Level
  - Body movement to operate joint/TD via dual cable
    - Shoulder depression/extension/abduction
    - “Down, back and out” to lock/unlock elbow joint

Body powered prosthesis

Body powered prosthesis



Myoelectric prosthesis

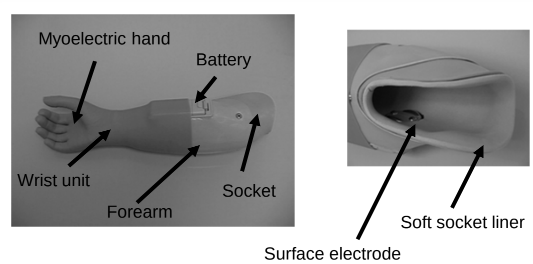
- Advantages
  - No harness required
  - Better cosmesis
  - Less muscle strength needed
- Disadvantages
  - More expensive
  - Heavier
  - More maintenance needed

Myoelectric prosthesis

Common myoelectric sites:

- Transradial level: Intact wrist flexors/extensors
- Transhumeral level: Intact biceps/triceps
- Shoulder disarticulation: Intact pectoralis/latissimus dorsi

Self Suspension



Wrist Disarticulation Options

- Control system: passive, cable or myoelectric
- Socket design: soft interface, rigid frame
- Suspension: suction, harness (figure-9)
- Thin wrist unit
- Terminal device: hook, hand, robotic, specialty

Transradial Options

- Control system: passive, cable or myoelectric
- Socket design: single wall or double wall
- Suction suspension: wet/dry fit into hard socket or gel liner
- Harness suspension: Figure 9 (long) or Figure 8 (short)
- Flexible elbow hinge to triceps cuff
- Wrist units: Friction, quick disconnect, flexion
- Terminal device: hook, hand, robotic, specialty

Elbow Disarticulation Options

- Control system: passive, cable, myoelectric or hybrid
- Socket design: single wall
- Suction suspension, self-suspending
- Harness suspension: Figure 8
- External elbow joints
- Forearm shell
- Wrist units: Friction, quick disconnect, flexion
- Terminal device: hook, hand, robotic, specialty

Transhumeral Options

- Control system: passive, cable, myo or hybrid
- Socket design: interface, single/double
- Suction suspension (gel liner or wet fit)
- Harness suspension: Figure 8, shoulder saddle with chest strap
- Mechanical elbow joints (internal locking)
- Electric elbow joints (depending on length)
- Wrist units: Friction, quick disconnect, flexion
- Terminal device: hook, hand, robotic, specialty

Shoulder Disarticulation Options

- May consider shoulder cap for pain control
- Cosmetic vs. functional prosthesis
- Socket designs (passive, cable, myo, hybrid)
- Harness designs (figure-8, cross-chest)
- Shoulder joints: passive, switch
- Elbow joints: mechanical, electric (switch vs. myo)
- Wrist units: Friction, quick disconnect, flexion
- Terminal device: hook, hand, robotic, specialty

Functional Goals- U/L UE Amputee

- Independent in donning and doffing prosthesis
- Independent in activities of daily living
- Can write legibly with remaining hand
- Drives and has returned to work
- Can tie laces with one hand and use a button hook
- Has prepared a meal in the kitchen and has been instructed in use of adaptive equipment
- Wears prosthesis daily and uses for bimanual activities at least 25% of the time

Functional Goals- B/L UE Amputee

- Transradial amputee
  - Achieve independence with ADLs
- Transhumeral amputee
  - 25-50% achieve independence with ADLs
  - Remaining require minimal to moderate assistance
- Shoulder disarticulation
  - Dependent for all ADLs, exceptions include congenital amputees who become independent with foot skills

Usage

- Wright, 1994:
  - 135 major upper limb amputations (above wrist)
  - Usage rate by levels:
    - Wrist disarticulation: 54%
    - Below elbow: 94%
    - Above elbow: 43%
    - Shoulder disarticulation or forequarter: 40%
- Graham, 2006: Upper limb / Ireland
  - 56% used their prosthesis functionally
  - 34% used their prosthesis cosmetically

Usage

- Melendez, 1988:
  - Upper limb amputees who did not use prosthesis attributed their choice to a lack of education and information on prosthetic devices
- Biofeedback therapy
  - Computer based technology enables upper limb amputees to train to use myoelectric prosthetic devices while waiting to be fit for their prosthesis
  - Allows for early muscle strengthening and retraining

What is this?

Question

1. Young adult presents with traumatic injury to distal upper extremity and the orthopedic surgeon is deciding between an elbow disarticulation and a transhumeral amputation. In your discussion, you state one benefit of the elbow disarticulation level is:

a. Control of the terminal device will be easier
b. A stronger, more functional elbow joint can be fabricated.
c. A more durable prosthesis can be fabricated.
d. Fitting of the myoelectric prosthesis is easier.
e. Heterotopic ossification of the humerus is avoided.

Answer

1. Young adult presents with traumatic injury to distal upper extremity and the orthopedic surgeon is deciding between an elbow disarticulation and a transhumeral amputation. In your discussion, you state one benefit of the elbow disarticulation level is:

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e. Heterotopic ossification of the humerus is avoided.

Question

2. The primary bodily control motion required for opening the terminal device of a standard transradial prosthesis is:

a. Glenohumeral flexion.
b. Glenohumeral extension.
c. Glenohumeral abduction.
d. Biscapular adduction.
e. Glenohumeral and biscapular adduction.

Answer

2. The primary bodily control motion required for opening the terminal device of a standard transradial prosthesis is:

a. Glenohumeral flexion.
b. Glenohumeral extension.
c. Glenohumeral abduction.
d. Biscapular adduction.
e. Glenohumeral and biscapular adduction.

Question

3. The bodily control motion required to lock or unlock the prosthetic elbow of a standard transhumeral prosthesis is:

a. shoulder depression, glenohumeral flexion and abduction.
b. shoulder depression, glenohumeral extension and abduction.
c. shoulder elevation, glenohumeral flexion and abduction.
d. shoulder elevation, glenohumeral extension and abduction.
e. biscapular abduction, shoulder depression and abduction.

Answer

3. The bodily control motion required to lock or unlock the prosthetic elbow of a standard transhumeral prosthesis is:

a. shoulder depression, glenohumeral flexion and abduction.
b. shoulder depression, glenohumeral extension and abduction.
c. shoulder elevation, glenohumeral flexion and abduction.
d. shoulder elevation, glenohumeral extension and abduction.
e. biscapular abduction, shoulder depression and abduction.

Question

4. In a standard transradial prosthesis, when terminal device operation close to the midline of the body is required, as when buttoning a shirt, body motion necessary to operate the terminal device is:

a. shoulder depression.
b. shoulder elevation.
c. scapular retraction.
d. scapular protraction.
e. glenohumeral abduction.

Answer

4. In a standard transradial prosthesis, when terminal device operation close to the midline of the body is required, as when buttoning a shirt, body motion necessary to operate the terminal device is:

a. shoulder depression.
b. shoulder elevation.
c. scapular retraction
d. scapular protraction.
e. glenohumeral abduction.

Thank you