FILLING THE GAPS WITH TODAY'S PROSTHETICS

LEIF NELSON PT, DPT, ATP, CSCS

DISCLAIMER 1/2
Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government, and shall not be used for advertising or product endorsement purposes.

DISCLAIMER 2/2
None of the material presented within this course represents the views of the Department of Veterans Affairs or the United States Government.

OBJECTIVES
- To become familiar with most recent advances in prosthetics that are currently available
- To learn tips to train your clients with these state of the art devices
- To learn what is on the horizon in prosthetic and orthotic rehabilitation
- Understand capabilities sport specific prostheses

DEMOGRAPHICS AND STATISTICS OF LIMB LOSS
DEMOGRAPHICS OF LIMB LOSS IN RECENT WARS

- As of January 1, 2013:
  - 1581 OEF/OIF/OND servicemembers with major limb amputations
  - 30% have multiple limb amputations
  - 17% have upper limb amputations

AMPUTATION VS. LIMB SALVAGE IN COMBAT VETERANS

- Melcer et al. J Trauma Acute Care Surg. 2013
- Early amputation correlated with decreased adverse health outcomes vs. limb salvage

HETEROTOPIC OSSIFICATION

- Abnormal bone growth
- Common in amputations secondary to blast injuries of returning service men and women

HETERO OTIC OSSIFICATION

DEMographics OF VETERANS

- 7800+ new amputations performed in 2012
- Most common cause in vascular disease and/or diabetes
- 40,000 Veterans with limb loss treated in VA system each year

WHAT IS THE FREQUENCY OF AMPUTATION IN THE US?

- >185,000 new amputations performed each year
- As of 2008, there are nearly 2 million people with limb loss (excluding fingers and toes) in the United States
- The prevalence rate is ~4.9 per 1,000 persons. That’s nearly one out of every 200 people!

LIMB LOSS IN THE UNITED STATES

- 82% due to vascular issues
- The prevalence rate is highest among people aged 65 years and older ~ 19.4 per 1,000.
Causes of Amputations
- Vascular Disease: 82%
- Trauma: 11%
- Tumors: 3%
- Congenital: 4%

FILLING THE GAPS: PROSTHETIC FEET

FOOT/ANKLE COMPONENT OF THE PROSTHESIS
- Interface between socket/shank and environment
- Base for weight bearing
- Absorb shock
- Provide energy for heel rise/push off
- Provide dynamic/visual cosmesis

SOLID ANKLE CUSHION HEEL S.A.C.H.
SACH BIOMECHANICS

- Clinical Experiences with the S.A.C.H. Foot Prosthesis
- Rejection rate of 3/123 = 2.4%
- Prosthetists polled stated under 1%
- Maintenance - minimal, repairs rare.
- Pt's state: better shock absorption and smoothness of gait, increased endurance.

JAIPUR FOOT

- 2 plates or leaf springs forming the keel
- Stores and returns more energy than previous foot-ankle assemblies

FLEX FOOT / VARI-FLEX WITH EVO (OSSUR)

- Flex Foot (Original)
- Vari-Flex with EVO (Current)
RENEGADE
(BY FREEDOM INNOVATIONS)

C-WALK

- Physiologic gait due to coil

C-WALK VS. FLEX-FOOT VS. S.A.C.H
PHYSIOLOGIC MEASUREMENTS IN PEOPLE WITH TT AMPUTATION.

  - C-Walk: Trend of improved physiologic response
  - Flex-Foot: lower age predicted HR and RPE values
  - All else non-significant.

ENERGY RETURN
SACH VS. SEATTLE VS. FLEX FOOT

- Energy return
  - Sach 39%
  - Seattle 71%
  - Flex Foot 89%
  - Intact Plantarflexors 246%

SOLEUS (COLLEGE PARK)
OTHER HIGH PROFILE FEET

- Modular III
- Triton
- Reflex Rot

FLEX RUN

BLAKE LEEPER

RUNNING AFTER LIMB LOSS

Unilateral
- Bilateral

FILLAUER WAVE SPORT

- Wave Spring
- Direct Mount Pyramid
- Full Length Keel

ENDOLITE ECHELON

- Hydraulic ankle
- Adjusts to inclines/declines
- Allows foot flat in sitting
- Prosthetist Polled
  - Great for level walking
  - Great for ramps
  - Poor at high speeds
  - Poor for initial sit to stand
TRUSTEP (COLLEGE PARK)

ADJUSTABLE HEEL HEIGHT

Computerized Ankle
- Articulated
- Multi-axial
- Energy Storing
  - Deflection plate – carbon keel
- Computer sensors adjust ankle angle for hills, stairs, transfers
- Low to medium impact

PROPRIO FOOT
- Sense: accelerometers sample ankle motion >1000 times/sec.
- Powered articulating ankle, but does NOT generate power
GOOD FOR PEOPLE WHO NEGOTIATE

PROPRIO FOOT
Turned On

ÉLAN

BIOM BY IWALK

- Weight: 4.5 lbs
- 3 Microprocessors
- 4 Foot Sensors
- Gyrometers

BIOM WALKING

Renegade

BIOM DECLINE
Leif Nelson, DPT, ATP, CSCS
TFA COMPONENTS
- Foot and ankle
- Shank / Pylon
  - Can have a component proximal to knee
- Knee
- Socket
  - Plug-Fit, Quadrilateral & Ischial Containment
- Interface
  - Liner, Residual Limb Sock
- Suspension
  - Pin, Suction, Belt, Shoulder harness

FILLING THE GAPS: PROSTHETIC KNEES

SINGLE AXIS VARIABLE FRICTION
- Pneumatic
- Hydraulic
- Microprocessor Controlled

HYDRAULIC SWING AND STANCE
- Commonly called “SNS”
- Pros:
  - Separate hydraulic setting for swing and stance
  - Popular
  - Durable
  - High functioning at variable cadences
- Cons:
  - Maybe affected by extreme temperatures
  - Valves can fail

HYDRAULIC KNEE: MAUCH (OSSUR)

HYDRAULIC “SWING N STANCE”? 
- Switches between swing & stance phase control (2 separate resistances)
- Stance phase activated by knee extension at terminal swing/initial contact
- Swing phase activated by knee extension at terminal stance
- Stumble recovery
  - Not as reliable as microprocessor
- U-ring can be set to lock knee in extension
- U-ring can be set to put knee in free swing
HYDRAULIC STANCE AND SWING

Other fun facts:
- Can be configured for use in Sports applications
- K4
- Hydraulic Knees are Gold standard for K3 in many clinics

HYDRAULIC SWING AND STANCE

KX06 (Endolite)
- Hydraulic swing and stance
- Polycentric Knee
  Benefits of Polycentric Knees include:
  - Knee Center of Rotation relocates throughout the ROM
  - Shortens limb during swing phase
  - Highly Stable in stance due to posterior position relative to weight line

MICROPROCESSOR KNEES

HYDRAULIC VS. MICROPROCESSOR KNEE: ENERGY EXPENDITURE

- Multiple studies show hydraulic knee is same as microprocessor on level ground walking
- Kenton et al; Arch PM&R, Vol 89 July 2008 (n=15)
  - Participants perceived it was easier to walk with C-Leg vs. Hydraulic Knee
  - Decreased energy expenditure in free living environment via urinalysis of ingested isotopes

BENEFITS OF C-LEG VS. HYDRAULIC KNEE

Kahle et al, JRRD (2008)
- n=21
  - Decr stumbles reported
  - Decr falls reported
  - Incr walking speed
  - Incr stair descent
  - 74% of participants preferred C-Leg

Hafner et al., Arch PM&R (2009)
- n=21
  - Indoor walking performance was same
  - Incr stair descent
  - Improved FTV descent time
  - Decr stumbles reported
  - Decr falls reported
  - No difference in cognitive demand
  - Decr in difficulty with multi-tasking reported
  - Subjects preferred C-Leg

MICROPROCESSOR KNEES

- Able to adapt to the widest variance of cadences
- Currently defined as appropriate for K3 level
- Community ambulators
- Could this be appropriate for K2?
- Many of the benefits of hydraulic knee units
  - Although mechanism of control varies
  - Must be charged
  - Battery life varies from 1 day to 1 week
  - Most expensive of all knees
  - Typically not as durable as less complex knees
- Microprocessor Controlled swing and stance
  - Hydraulics unit controlled by programmed microprocessor
  - Stair mode
  - 2nd activity mode

- Specs
  - Weight limit 125 kg
  - Weighs 1.1 kg
  - 125 degrees of flexion

**C-Leg**

**Microprocessor Stance and Swing**

**And hydraulic Swing**

**Compact by Otto Bock**

**Genium by Otto Bock**

- 5 alternate modes
- Gyroscopes/accelerometers
- Walking backwards safer
- Shorter pylon
- More options for feet
- Free Swing in Sitting
- Stair ascending mode*
- Running Mode and Rubber Cover
- Water Proof

**X3 AND GENIUM**

**X3**
- 5 alternate modes
- Gyroscopes/accelerometers
- Walking backwards safer
- Shorter pylon
- More options for feet
- Free Swing in Sitting
- Stair ascending mode*

**Genium**
- 5 alternate modes
- Gyroscopes/accelerometers
- Walking backwards safer
- Shorter pylon
- More options for feet
- Free Swing in Sitting
- Stair ascending mode*

**X2 GENIUM BY OTTO BOCK**

**Genium**

**C-Leg**

**X3**

**Orion (Endolite)**
- K3 Level
- Hydraulic AND Pneumatic Components
- Durable for a microprocessor

**Plić 2 (Freedom Innovations)**
- Microprocessor controlled hydraulic...
Microprocessor controls Magnetorheological fluid
Default mode is “swing” phase

Microprocessor Knee: Rheo

C-Leg vs. X2 walking

C-Leg

X2

Stance Flexion
C LEG VS. X2 UP STAIRS

CLEG VS. X2 HIGH SITTING

X2 SQUAT

63 YEAR OLD MALE ON GENIUM

TRAINING GENIUM UP STAIRS

GAIT AND FUNCTIONAL MOBILITY

Balanced Torques
Symmetry
Less Pain
Improved QOL
Increased Function
OSTEOARTHRITIS AND KNEE PAIN

- Norvell et al, Arch PM&R 2005
- VA Study
- Knee pain 40% amputees vs. 20% nonamputees
- Knee OA 16.1% amputees vs. 11.7% nonamputees
- Pieter et al, Arch PM&R 2009
- N=78 KD or AKA
- Hip OA 14%
- Knee OA 27%
- Both Hip and Knee OA 10.3%
- General Population <2%

BACK PAIN

- Taghipour et al, J Orthop Trauma 2009
- VA Study
- Knee pain 40% amputees vs. 20% nonamputees
- Knee OA 16.1% amputees vs. 11.7% nonamputees
- Health related quality of life in 141 amputee war veterans
- Low Back Pain and Articular Pain in Sound Leg are two main factors in decre HRQOL scores
- Kulkarni et al, Clinical Rehabil 2005
- 81% Transfemoral Amputees had back pain
- 62% or Transtibial Amputees had back pain
- Little to degenerative disc disease in back

CASE STUDY:
MICROPROCESSOR KNEE FOR K2 AMBULATOR

PARAMETERS

PARAMETERS
PARAMETERS

COSMESIS

LIMB LOSS @ LEVEL OF HIP DISARTICULATION

TRADITIONAL HIP JOINT

HELIX HIP 3D

TIMED UP AND GO

7E7

Helix

7E7 SPEED OF AMBULATION

- **Avg**
  - 1.07 m/s
  - 0.56 m/s

Walking Speed by Gender and Age

GOAL: IMPROVE FUNCTION

FUNCTION, COSMESIS, PRESERVATION
COMMUNITY MOBILITY

STAIRS AND CURBS

- Ascent
  - Step-to leading with intact side
- Descent
  - Beginner: Step-to leading with prosthetic side
  - Advanced: Step over Step
    - Prosthetic foot 50-75% off the step
- Start training in parallel bars and progress as appropriate

STAIR TRAINING

- Architectural barriers
  - Must be mastered for community independence
- Stairs negotiation
  - Sound limb ascends first - descends last
- Normal step-through pattern
  - Foot must be ½ to ¾ off step
  - Transtibial should be able to achieve
    - Transfemoral with Microprocessor Knee have potential to achieve
      - Also a properly configured hydraulic knee

RAMP TRAINING

- Beginner or Household Ambulator
  - Prosthesis downhill for ascent and descent
  - Diagonal pattern is progression
DECLINE MOVING FASTER.....

UPPER EXTREMITY PROSTHETICS

ILIMB WITH BOSTON ELBOW

- 64 y/o male
- 40 yrs w/o prosthesis
- Uses it daily
- Lift 7 lbs with elbow, hold 50 lbs when locked

Key tip:
- Need to teach user to adjust thumb for different grips
MYOELECTRIC DISTAL ATTACHMENTS
Sensor Hand
Gripher

PRODIGIT
- 38 year old male
- IED Blast 2004
- Right above elbow amputation
- Left Thumb amputation
SPORTS SPECIFIC PROSTHETIC LIMBS

NATALIE DU TOIT

SWIMMING
- Custom
- "J" Shaped or "C" Shaped
- No Heel
- Knee joint!

OTHER CUSTOM SWIM OPTIONS

RUNNING LIMBS
- "J" Shaped or "C" Shaped
- No Heel
- Knee joint!

Key Tips
- Practice on everyday foot getting over toe
- Agility drills
3S80 (OTTO BOCK)

BARTLETT TENDON KNEE

CYCLING

"Criterion" by TR6
BARLETT TENDON KNEE SKIING

TRANSFEMORAL SNOWBOARDING

XT9 Walking Torsion

Leif Nelson, DPT, ATP, CSCS
SKIING INJURY

TRANSTIBIAL SNOWBOARDING

HAMMERHEAD BY TRS

Leif Nelson, DPT, ATP, CSCS
CASE STUDY: BILATERAL TRANSRADIAL AMPUTEE

67 Y/O Vietnam Veteran – “I want to play golf, make me a golf arm”

“The Bazooka”

Veterans on Par Golf Clinic
3 Day Golf Clinic: Instruction from local PGA Pros and 3D Golf Swing Analysis
Goal: Improving function through sport

THE FUTURE
POWER KNEE

- Weighs 7 lbs
- Max flexion 120 deg
- Max weight 275 lbs
- 3.5-7.5 hours on 1 battery
- Thigh + Shin Accelerometers
- Torque Sensor
- Ground Contact Switch
- Logs usage

STAIRS UP

WE NEED MORE POWER!

- iWalk Transfemoral Prosthesis
- Vanderbilt Powered Knee and Ankle

UPPER EXTREMITY ROBOTIC PROSTHETICS

- Non-invasive Brain Controlled
- Targeted Muscle Reinnervation

INVASIVE BRAIN CONTROLLED
DEKA ARM

- "Revolutionizing Prosthetics"
- DARPA funded DEKA Arm
- Was originally called “Luke” arm
- 10 powered degrees of freedom
- 18 total degrees of freedom
- 6 grips, more can be programmed
- Simultaneous joint control
- Intuitive control options

Controlling the Arm

- Each user has their own unique control scheme based on preference and ability:
  - Foot controls(s)
  - FSRs
  - IMUs
  - Myoelectric (muscles)
  - Pneumatic Bladder controls
  - Control switches
    - Triggered by reaction

HAND/ARM TRANSPLANT

Thank You!
leif.nelson@nyu.edu