Impact of Bionic Legs Technology: Improving Proper Gait Mechanics

Mark Manning
Brief History of Bionic Prosthesis

• 1960
  – Sensors were placed directly on vestigial limb
    • Used to pick up electrical impulses
  – Limitation: Impulses were being picked up from multiple muscles
    • Inhibited performance

• 1971 (Jaipur Foot)
  – Developed by an Indian surgeon
    • Viewed as the pinnacle of prosthetic science
    • Mimiced shape of foot, failed to return loss of function
History of Touch Bionics

• 1993 (David Gow- Bioengineering Centre)
  – Developed first partial hand system
    • 1998 (First Electronically Powered Shoulder)
• 2007 (Touch Bionics releases I-limb)
  – First Prosthetic Hand with articulating fingers
    • Silicone covering to mimic human skin
• April 2016 (Ossur partners with Touch Bionics)
  – Non-invasive orthopaedics
    • Improve mobility through braces & prosthetic limbs
Normal Gait Biomechanics

• Stance Phase
  – Heel Strike (lasts until foot on the ground)
  – Early Flat Foot (moment entire foot is on the ground: COG)
    • Allows foot to act as a shock absorber
  – Early Heel Rise (COG passes in front of neutral)
    • Foot becomes rigid lever, propels body forward
  – Toe Off (start of swing phase)

• Swing Phase
  – Running (involves ‘float’ phase= both feet elevated off the ground)
Common Foot/Ankle Prosthesis Currently on the Market:

• SACH (Solid Ankle-Cushion Heel)
  – Foam cosmetic foot shaped
    • Wedge cushion in the heel, compresses with each step
      – Internal supportive structure

• Single/Multi Axis Ankle
  – Hinged ankle joint
    • Rubber Bumpers absorbs ankle motion caused by body weight
  – Multi-axis: Permits rocking motion
    • Insufficient stored energy return
Foot/Ankle Prosthesis: Utilizing in Stored Energy

- ID25, IC40, Genesis II, Talux Foot
- Luxon DP, Modular III, Variflex Flex Foot
  - Internal structure acts as a spring mechanism
    - Spring stores energy
    - Energy is returned to amputee, provides forward propulsion as ‘toes’ leave ground
  - Terrain adapting features
    - Absorb irregularities on ground
    - Improve performance on inclined surface
Common Prosthetic Knees for Artificial Limbs

• Single Axis Constant Friction Knee
  – Set for each patient’s walking speed
    • Stiffens if person walks slower

• Pneumatic & Hydraulic Swing Control Knee
  – Uses principles of fluid mechanics
    • Varies resistance as user changes walking speed
    • Prosthetic always remains in the correct position during heel contact
Limitations on Normal Gait Mechanics

• Carbon-Fiber Based Prosthetics
  – Devices are overly stiff leading to chronic back problems
  – Spring mechanism replaces normal gait
    • Shift in balance can lead to joint problems
  – Cannot mimic natural gait patterns
    • Causes patients to compensate by using other muscle groups
      – Can eventually leads to muscle degeneration and osteoarthritis
First Step in Bionic Legs: BiOM Ankle System

- Developed by Hugh Herr at MIT
  - Biomechatronics Group
- Works independently from the brain
- Simulates action of ankle, Achilles tendon and calf muscles
  - Propels patient upwards and forward with each step
  - Robotics replace muscle and tendon function in the lower limb
- Components:
  - Lithium, Polymer Battery
  - Microprocessors
  - Sensors
Advancements in Prosthetic Technology

• Carbon-fiber spring controls each step
  – Toe-Off (battery-powered motor)
  – Heel Strike (loads spring w/ Potential Energy)

• Algorithm measures the angle and speed of each successive heel strike
  – Provides user with the ability to adjust to real-time changes in terrain
Advantages from the BiOM Ankle System

• Energy return
  – BiOM: 100-200% of body's potential energy (generated from heel strike) is returned to the system
  – Passive Carbon-Fiber: only returns roughly 50-90% of the patients downward energy

• Reaction to Changes in Environment
  – Microprocessors and sensors:
    – Allows BiOM to mimic the body’s natural motion
BiOM Ankle System: Human Impact

• Improving Amputee Patients overall Quality of Life
  – Replaces loss of muscle function
  – Exhibits less stress of the prosthetic and user

• Allows normal/proper gait mechanics
  – Stimulates natural human motion
    • Improves balance and sustains muscular function
Future Research for the BiOM Ankle System

• Improvements in normal gait motion
  – Ability to walk further(distance) and faster(speed)
    • Body expends less energy
  – Decrease muscle fatigue and pain experienced by users

• Allow rapid, real-time response to changes
  – Improve balance
  – Reduces the risk of falling
Revolutionary Research in Neurologically Controlled Prosthesis

• Greater difficulty replacing functional control in lower extremity prosthetics
  – Less conscious control required for lower extremity movement
  – Self-controls occurs through innate reflexes
    • Triggered by the spinal cord
    • Automatically adjusted by neuromuscular system
Development of the IMES (Implanted Myoelectric Sensor)

• Alfred Mann Foundation
  – Implanted to remnant muscles in limb
    • Coiled Wire-receiver (picks up impulses and transmitted wirelessly to robotic limb computer)

• Robotic Limb and IMES
  – Cybinetic spinal cord
    • Delivers unconsicous command to prosthesis
    • Enables instantaneous control of movmements
      – Reflexes delivers myoelectric impulses which control the Bionic prosthetic
Ossur Sensor-Linked Limbs

• Components
  – IMES Sensors (embedded in muscle tissue)
    • Adjusts angle of foot during diff. points in stride
  – Proprio Foot (motorized battery powered ankle)

• Readily compatible with bionic feet, knees and legs
  – Computerized smart limbs
    • Capable of real-time learning
    • Self-adjusting gait patterns
      – Adapts to changes in terrain and speed
Subconscious Control over a Prosthetic Limb

• Prosthesis moves based on the location of the activated sensors
  – Sensors are implanted in either the front or rear of the prosthesis
    • Respond to impulses generated in local muscle tissue

• Electrical impulse is delivered from the brain to the base of the leg
  – Sensors transmit signal wirelessly to proprio foot
Improvements in Gait Mechanics with Ossur Sensor-Linked Limbs

- Commands reach the foot before residual muscles are able to contract
  - Prevents unnatural lag from occurring
  - Patient elicits subconscious, real-time control
    - Allows quicker more natural response time and movement
  - Re-distributes patient's body weight
- Preventing further complications due to muscular compensation
Sensor-Linked Limb: Maintaining Muscular Functioning

• Patient is required to actively use remaining lower leg muscles
  – Reverses deterioration of muscle fibers from occurring in amputee patients
  – Restores some level of functioning in the limb
  – Promotes muscle growth, muscle endurance and stamina
Ossur: Minimizing Invasive Surgical Interventions

• Surgery Intervention
  – 15 minute procedure conducted by an orthopedic surgeon
  – Less than 1 cm incisions made to place sensors within muscle tissue
    • Sensors don't have to be attached to specific nerves
  – Powered by a magnetic coil
    • Eliminates need to replace battery
Limitations in the Field of Bionics

• BiOM T2
  – Cost: $40,000
    • Ossur Sensor-Linked Limb (TBD)
    • Over 900 BiOM ankle systems currently being used
      • Military Veterans (50%)
  – Insurance
    • Reduces prevalence of:
      – Dependence on painkillers (potential drug abuse)
      – Osteoarthritis treatments
Future Research

• Large Scale Clinical trials
  – 3-5 years away from released to public
• Non-invasive surgical options
• Full user-control over device
• Increase accessibility for amputee patients
  – Important in preventing muscle atrophy from occurring
Works Cited


• Slater, Matthew. "Is This the Future of Robotic Legs?" *Smithsonian Magazine*. Smithsonian, Nov. 2014. Web. 6 Nov. 2016.
