History of Lower-Limb Prosthetics

- 424 B.C. to 1 B.C
  - Bronze iron leg with wooden core for below knee

- The Dark Ages (476 to 1000)
  - Peg Leg or aesthetic protheses

- Mid- to late 1500s
  - Above-knee fixed position prosthetic

- The 17th through 19th centuries
  - First non-locking below knee prosthetic
  - Articulate knee and ankle joints on prosthetics

- Modern times
  - Flex foot and blade prosthetics
Upper Limb Prosthetics in Sport

- Baseball
- Cycling
- Fishing
- Golf
- Kayaking
- Skiing

- Most are for transradial or transhumerus amputees
- Consist mainly of gripping and maneuvering apparatuses
- Sometimes the prosthetic may need to help support the athlete
- Often include interchangeable hands for ease of use
Lower Limb Prosthetics in Sport

- Cycling
- Golf
- Skiing/Snowboarding
- Swimming
- Running/Jogging
Cycling

- Possible for most lower limb amputees
- Used to reduce inter-limb asymmetry that results from one legged cycling
- Depending on location of amputation different joints can be used to allow for the most natural motion
Golf

- A basic leg prosthetic is normally used for golf.
- Due to the rotations involved in a golf swing, most amputees report greater discomfort than generated through everyday activities.
- A torsion adapter, a device designed to allow rotation of the limb, is used to reduce discomfort.
- These are typically for below-knee amputees but may also aid above-knee amputees with swing follow through.
General Sport

- Skiing/Snowboarding
  - Below-knee and foot prosthetics may be attached directly to boot
  - Main modifications include a torsion adaptor-like device to allow for more rotation or the use of a flex foot design to better mimic a human ankle.

- Swimming
  - Specific foot of prosthetic designed to mimic the motion and fluid mechanical properties of human foot or specific "flipper feet" may be used.
Running & Jogging

- Because of the relative simplicity of the running motions as compared to other sport motions there has been much more innovation in running prosthetics then in other fields.
- They have evolved from simple day to day prosthetics to specialised carbon fiber limbs.
Running Mechanics

- **Stance Phase**
  
  This is the time when the runner's foot is in contact with the ground.

- **Swing Phase**
  
  When the runner's leg is off the ground, moving into position to initiate another stance phase.
Stages of Stance Phase

- **Absorption**
  - Foot strike to midsupport

- **Propulsion**
  - Midsupport to takeoff
Swing Phase

- The purpose of this phase is to reset the leg in a position were the stance phase may be reinitiated
Oscar Pistorius

- Born: November 22\textsuperscript{nd}, 1986
- No fibula in both legs
- Legs amputated halfway between his knees and ankles
- Uses Flex-Foot Cheetah transtibial prosthetic
Van Phillips

- Water skiing accident in 1976
- Motorboat cut off his left leg
- Decided to build a better prosthesis for himself
- Wanted to remain active (i.e. sports)
Flex-Foot

- Van Phillips’ idea for a better prosthetic
- Inspired by the C-shape of the hind leg of a cheetah
Flex-Foot Inc.

- Founded in 1984
- Started developing and testing for Paralympians
- Some variation of original design used by 90% of Paralympian athletes
- Sold to Ossur in 2000 (Ossur is one of the world’s leading orthopaedics companies)
Flex-Foot Cheetah

- The blade used by Oscar Pistorius (also Jerome Singleton, Jonnie Peacock, April Holmes)
- Designed primarily for sporting purposes
- Custom-built, carbon fiber foot
- Both transtibial and transfemoral
Two Breakthroughs

- Energy storage and release
  - Possible because of the carbon fiber design

- Vertical shock absorption
  - Allows for more natural gait
  - Protects undamaged limb and any remaining joints from excessive shock
Energy Vector Optimization feature

- Comes from controlling how the ground reaction force is transferred to the prosthetic foot
- Allows for the development of the most natural gait
- Reduces fatigue and pressure on the good limb (if there is one) and back
- Ease of control of ankle in stance phase
Biomechanics of Oscar

- Swings his legs between strides 20% faster than regular sprinters with the same top speed
- Limbs are 20% lighter
- Approximately 20% lower force on the ground, over a longer period of time
- Slower to start but can sustain speed for longer
Figure 3. Mean ground reaction forces (vertical and anteroposterior) while sprinting at 9.2–9.5 ms\(^{-1}\). Forces are normalized to body mass and the time (%) is normalized to the stance phase. Data of the transtibial athlete is shown in red, and the forces of the able-bodied controls are in black.
ABLE-BODIED RUNNING VS. “BLADE RUNNING” [12]

Össur’s Flex-Foot Cheetah is a J-shaped, high performance carbon composite prosthetic sprinting foot that was designed to mimic the anatomical foot/ankle joint action of able-bodied runners. Since its 1997 introduction, the Flex-Foot Cheetah has been the standard in prosthetic feet for elite and recreational amputee athletes worldwide.

When running, the musculature of an able-bodied leg – including quadriceps, knee, calf and ankle – absorbs much of the energy generated every time the foot connects with the ground.

The Flex-Foot Cheetah’s “J” curve compresses at impact, storing energy and absorbing high levels of stress that would otherwise be absorbed by the amputee user’s knee, hip, and lower back.

An able-bodied foot and leg has been shown to return approximately 241% of its energy when running.

The Flex-Foot Cheetah is only one third as powerful as a native ankle, returning approximately 90% of its energy when running.
One analysis says that Pistorius is seven seconds faster over 400m than if his legs were functioning as normal biological limbs.

- He has a longer ground contact time.
- Can swing his legs faster than biological limbs.
- He has a lower ground reaction force.
- Because his legs do not tire some think that he could set world records in a 600m race.
References


References


