A Study on How Metabolic Benefits of a Powered Artificial Gastrocnemius Prosthetic Device Might Affect Hamstring Fatigue on Transtibial Amputees

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Goals of this Proposal:

- Analyze Metabolic Benefits of a Prosthetic with an Artificial Gastrocnemius
- Prove the NEED for the Improvement of Prosthetics

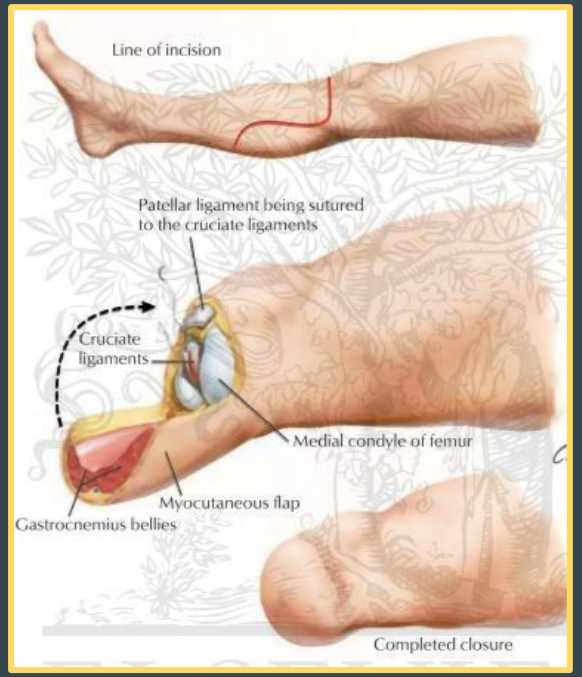
Function of the Gastrocnemius

- The gastrocnemius is part of a muscle group known as the plantar flexor muscles.
- The muscles in the plantar flexor group are critical for performing the functional roles of providing forward propulsion, body support, and leg swing initiation during level-ground walking [Pickel, et. Al].
- These muscles also contribute to the moment about the knee which in turn affects the moment, work, and fatigue about the hip.

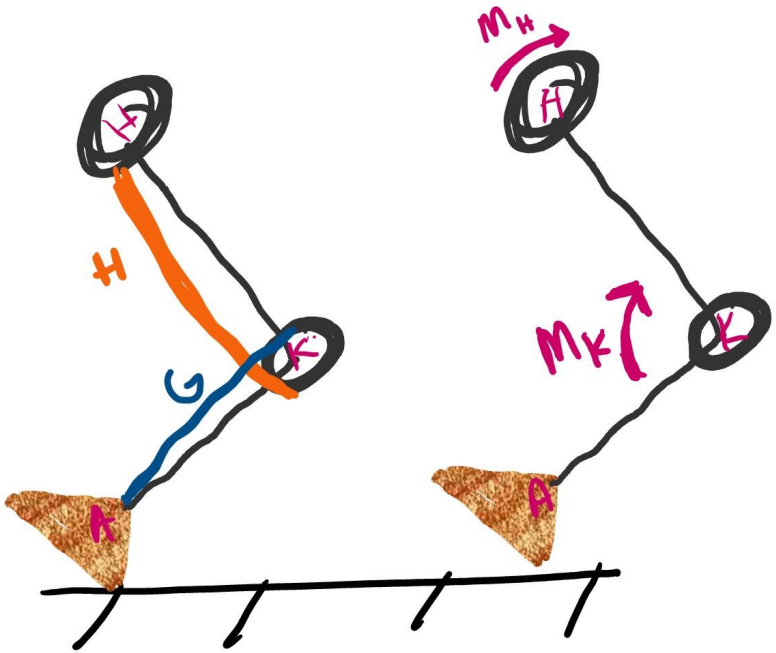
https://www.sportsinjuryclinic.net/sport-injuries/lower-leg/calf-pain/calf-strain

Transtibial Amputations or Below Knee Amputations

- Transtibial amputations (TTA) include the removal of the foot, ankle joint, distal tibia and fibula, and all the tissue structures surrounding that area.
- When this occurs, the surgeon takes the remaining muscle from the gastrocnemius and attaches it to the front of the tibia.
- Due to the lack of the plantar flexor muscles, amputees experience approximately a 15% increase in hip work due to compensation required in the hamstrings and other muscles.



<ahref="https://www.netterimages.com/transtibial-amputation-labeled-greene-orthopaedics-carlos-a-g-machado-8241.html">Illustration of Transtibial Amputation from the Netter Collection



$$M = F_m \cdot r_{m \cdot H}$$

$$W_{hip} = M_{hip} \cdot \theta$$

Why is this important?

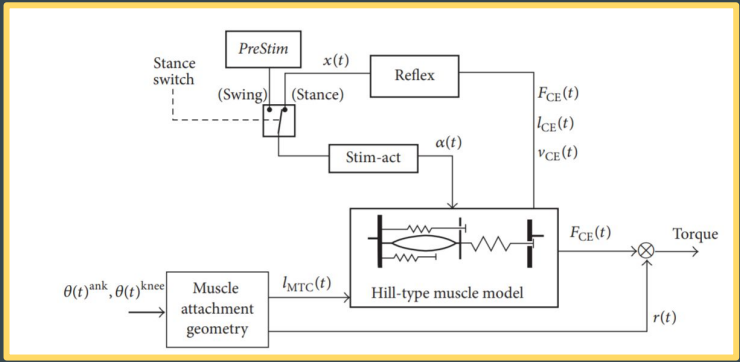
- Approximately 2.1 million people in the United States are Living with Limb Loss, and the majority of these are below knee amputees.
- Because these amputees lack their plantar flexor muscles, they experience an increase in fatigue of upper leg muscles including the hamstrings and the hip.
- They also exhibit an increased amount of falls which can lead to further injury.
- The typical designs of prostheses on the market do not mimic the properties that are lost due to the severed plantar flexor muscles.

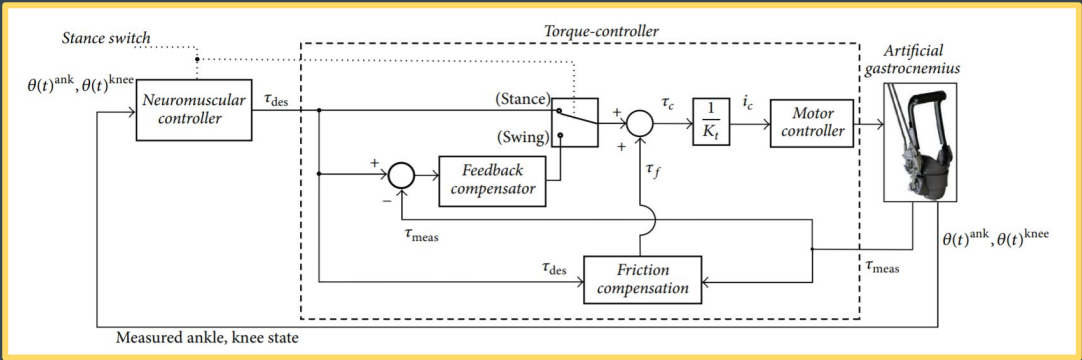
Previous Studies

- A lot of previous studies with TTA focus on angular momentum (H) of amputees. Because the plantar flexor muscles help regulate H which is important for balance, an amputee loses this regulation due to the amputation which could lead to increased amounts of falls.
- Some researchers have also studied active ankle-foot prosthesis vs. passive prosthesis to see if the active ankle-foot can mimic the lost plantar flexor muscles better than the passive prosthesis.
- Another researcher observed the effects of adding neuromuscular control to the prosthesis in hopes that it would mimic the plantar flexor muscles, but this too fell short.

Michael Eilenberg Artificial Gastroc Powered Prosthesis

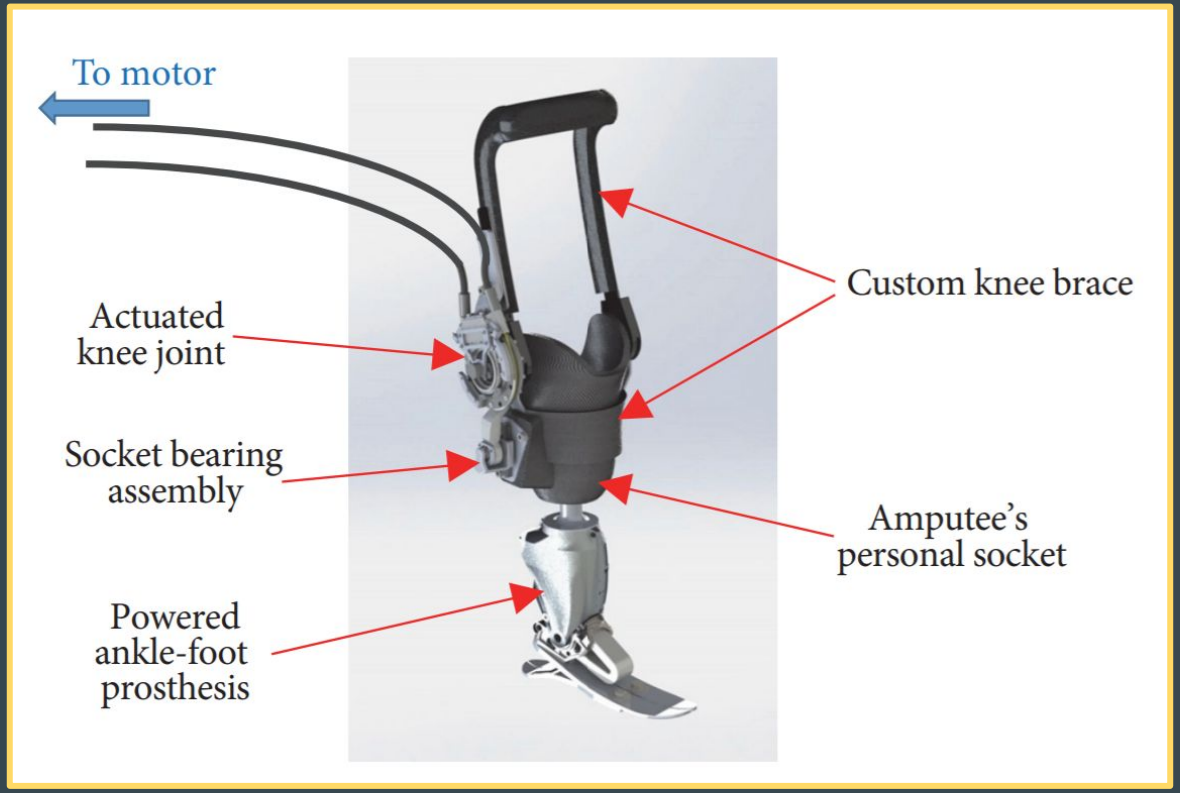
- The design for this prosthesis includes a motor driven module that has both a torque controller and neuromuscular controller paired with a commercial powered ankle-foot component.
- The goal of this design was to decrease hip positive work and flexion moments in hopes that it would decrease energy expenditure.





Michael F. Eilenberg, Jiun-Yih Kuan, and Hugh Herr, "Development and Evaluation of a Powered Artificial Gastrocnemius for Transtibial Amputee Gait," Journal of Robotics, vol. 2018, Article ID 5951965, 15 pages, 2018. https://doi.org/10.1155/2018/5951965.

Michael Eilenberg's Prosthetic Design



Our proposal is to take this artificial gastroc powered prosthesis and study whether it helps decrease the fatigue of the hamstring which will help decrease the amount of falls and increase the overall health of the amputee.

The Noraxon Ultium EMG

- <iframe title="vimeo-player" src="https://player.vimeo.com/video/239867804" width="640" height="360" frameborder="0" allowfullscreen></iframe>

The Trials

- Trial 1: The subject uses their every day prosthetic.
  - 30 minutes walking on a treadmill
  - 30 minutes walking on a treadmill that has a 60% higher incline
  - 30 steps up and down on a 1 foot block
- Trial 2: The subject wears Michael Eilenberg's prosthetic.
  - 30 minutes walking on a treadmill
  - 30 minutes walking on a treadmill that has a 60% higher incline
  - 30 steps up and down on a 1 foot block

http://downloads.hindawi.com/journals/jr/2018/5951965.pdf

Data Analysis

- Analysis will include peak voltage values, RMS (the average potential produced over a time period), and further Matlab computation.
- The data will be used to compute the moment and the hip positive work about the hip.

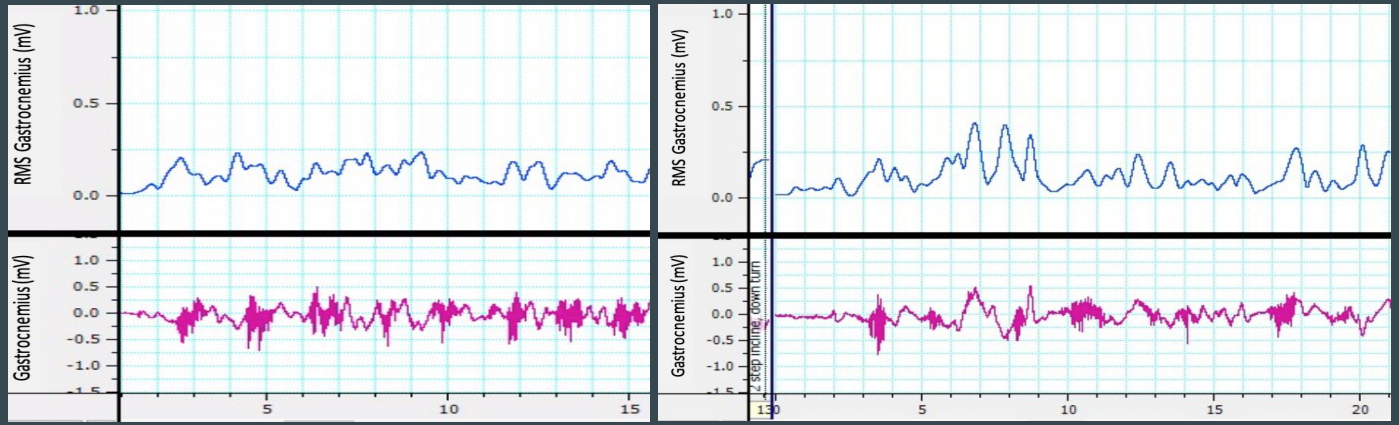
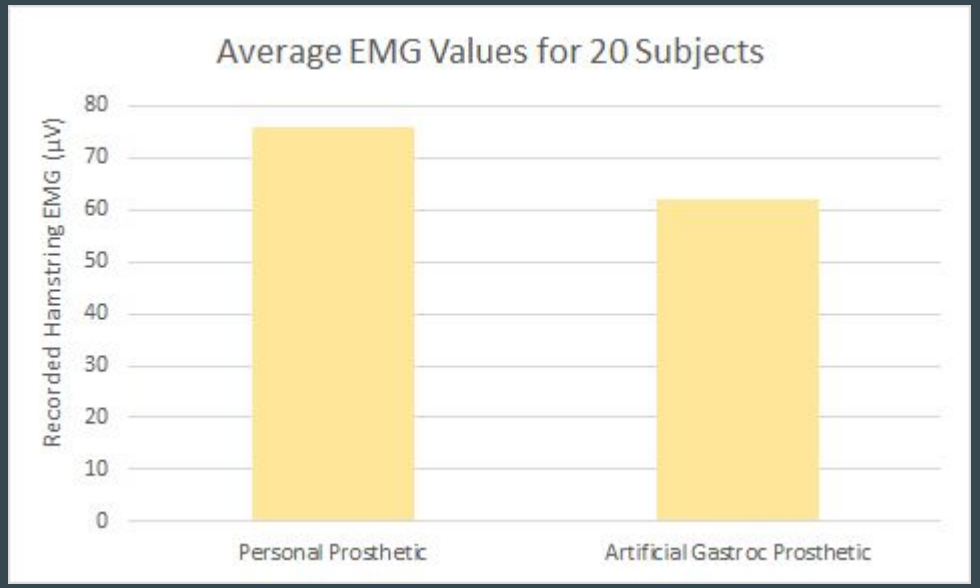


Figure 2: EMG data of a natural gastroc while the subject is (a) walking and (b) walking on a 9 degree incline.

Expected Results

- We expect that the artificial gastrocnemius prosthetic will decrease hamstring potential by at least 20%.



Questions?