ANKLE EXOSKELETON

Kaitlyn Buck, Tayluer Streat, Neil Thaker
Department of Mechanical Engineering
Embry-Riddle Aeronautical University
Daytona Beach, FL

INTRODUCTION

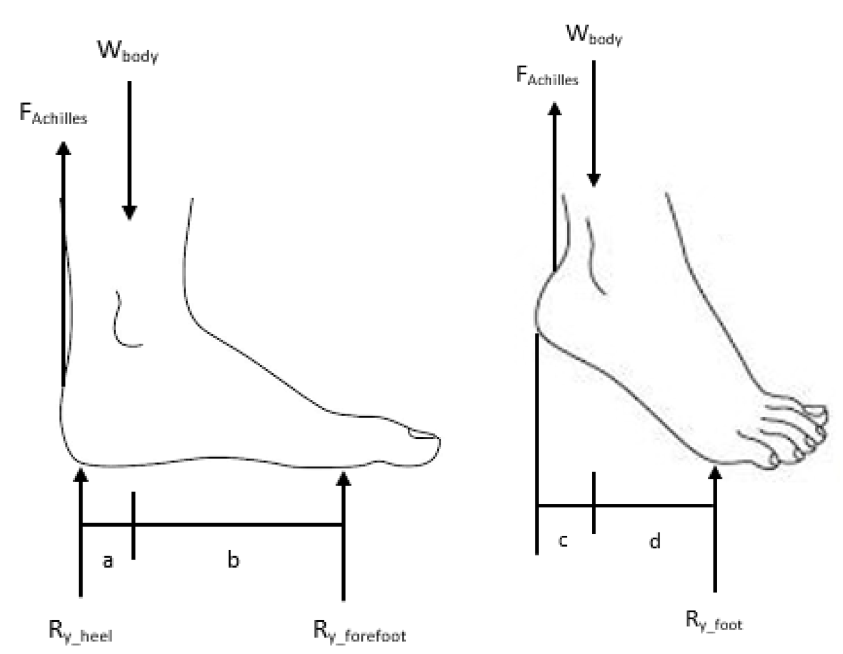
An exoskeleton is a wearable device that is powered by a motor, hydraulics, pneumatics or a combination of different technology to decrease for forces put on the body while also increasing the strength and endurance of the individual wearing the exoskeleton. One of the first exoskeleton's was created by General Electric; it was made with hydraulics and an electric bodysuit, but it was built to be too heavy for any use. The objective if this project is to develop a wearable device that will be able to enhance personal performance when walking and reduce the amount of work that the person must do in order to move. The ankle exoskeleton is designed to fit an average male of 5' 9" tall weighing 176 pounds [1].

SPECIFICATIONS

Based on research from literature and calculations the specifications for the ankle exoskeleton include:

- The speed of the exoskeleton shall be at least 61 RPM [2]
- The torque output from the motor shall match or exceed 10% of the maximum torque produced by the ankle which is 7.1 Nm

SCHEMATIC

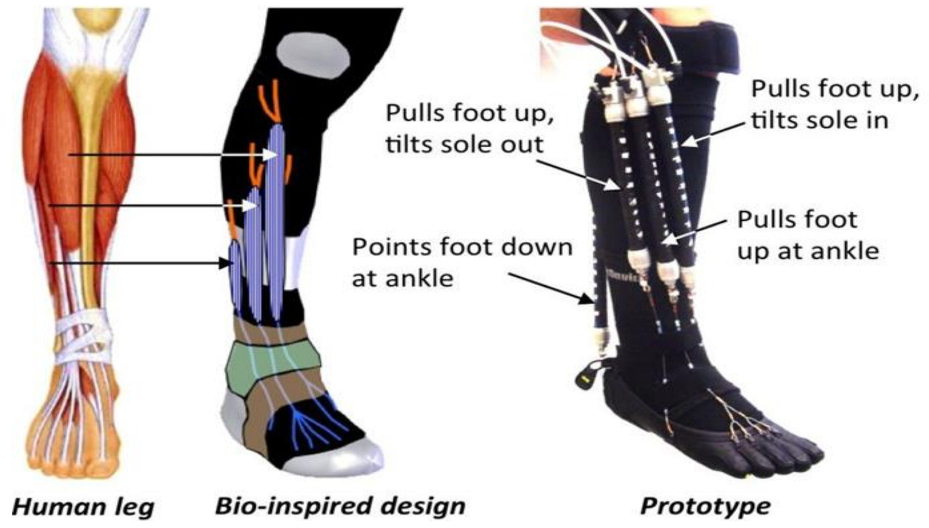


Variables	Value
W_{body}	775 N
$F_{Achilles}$	976.7 N [3]
R_{y_heel}	492.2 N
$R_{y\_forefoot}$	290.5 N
R_{y_foot}	201.7 N
a	0.0762 m
b	0.127 m
c	0.055 m
d	0.085 m
τ	74.5 Nm
ω	61.14 rpm [2]

ADDITIONAL RESEARCH

Soft Robotics (Pneumatic Muscles)

Most exoskeletons currently are rigid, which limits the degrees of freedom. Soft exoskeletons replicate the body's muscles, tendons, and ligaments using pneumatic artificial muscles (PAM) and allows for movement in more degrees of freedom. Researchers at Carnegie Mellon University created a wearable prototype using PAM for the lower leg. Three PAMs were implemented from the side to the front of the leg, and one was placed in the back to replicate the muscles used when walking. Steel cables were used to replicate the tendons that attach the muscles to the bone. A hyperelastic strain sensor was placed on the top and side of the ankle to collect data from the ankle during movement. The prototype was made to have a 27° range of motion, which is considered a normal walking gait. The drawback of this concept would include the weight. While the pneumatic exoskeleton itself is light, the weight of the air compressor required to control the PAMs would be cumbersome and inconvenient for the user. [4]



ABSTRACT

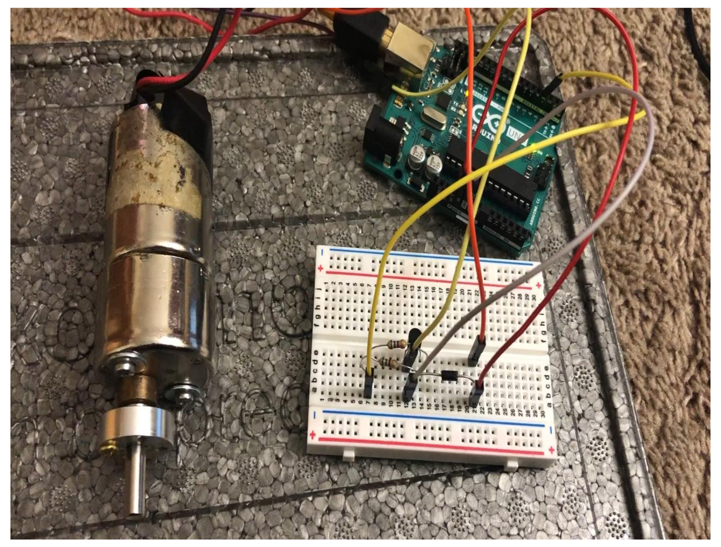
An exoskeleton is a wearable external support that reinforces and enhances human movement and performance. The exoskeleton will be powered by a motor that will sense human movement using electromyographic (EMG) sensors and move the exoskeleton in the same motion as the body segment that is being replicated. The goal of this project is to make the exoskeleton lightweight and able to match the speed of the ankle. The exoskeleton will be designed after an average male that is 5' 9" and 176 lbs. The wearable device will need to match the speed of the ankle which is 61 RPM [2] and be able to match or exceed 10% of the ankle's maximum torque which is 7.1 Nm. The exoskeleton will be made to allow one active degree of freedom in flexion and extension.

DESIGN CONCEPTS

The ankle exoskeleton will include a motor with a gear box and encoder to control the torque allowing the brace to move in flexion and extension. A pressure sensor will be attached in the heal of the brace to measure the pressure through the foot and EMG sensors will be placed on the calf to measure the muscle activation of the gastrocnemius when walking.

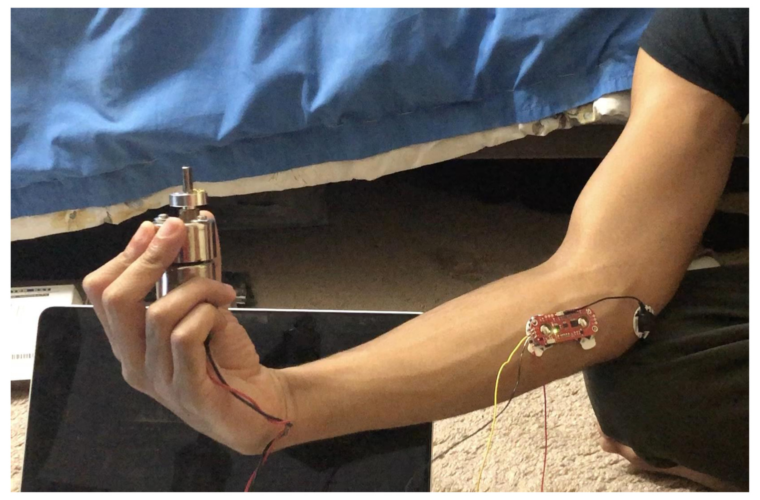
Fully assembled exoskeleton

Instrumentation of the motor system



RESULTS

Using an Arduino UNO and a square force-sensitive resistor, the force on foot when walking was able to be measured. Also, with the Arduino UNO and MyoWare muscle sensor, the muscle activation of the calf muscle was able to be obtained by connecting the MyoWare to the calf and the reference electrode to the shin. This electrode will be converted into a signal for the activation of the motor.



DISCUSSION

The ankle is a part of the body with high torque and speed. Both parameters were taken into consideration when selecting a motor, but there is a trade-off between the two because the motor that fits within the frame of the brace cannot satisfy both simultaneously. Since the goal of the exoskeleton is to enhance walking, the decision was to maintain the speed and draw back on the torque.

CONCLUSIONS

Research on the ankle was completed to obtain the torque along with calculations of forces and speed on the ankle. Preliminary testing has been done, and a model of the exoskeleton had been designed using computer-aided design (CAD). The next step for the team is to complete testing on the final assemble to achieve preferable specification.

REFERENCES

[1] Gill, S. (2018, February 14). "Is there an average weight for men?" *Medical News Today.*

[2] B.W. Stansfield, S.J. Hillman, M.E. Hazlewood, A.A. Lawson, A.M. Mann, *I.R. Loudon, et al., Sagittal joint kinematics, moments, and powers are pre-dominantly characterized by speed of progression, not age, in normal children, J. Pediatr. Orthop. 21 (2001) 403–411.*

[3] Woo SL, Johnson GA, Smith BA. Mathematical modeling of ligaments and tendons. *Journal of Biomechanical Engineering. 1993;115:468–473.*

[4] Coxworth, B. (2015, May 2). Soft pneumatic exoskeleton could be perfect for use in rehab. New Atlas.

ACKNOWLEDGMENTS

Dr. Victor Huayamave, Ignite Research Center, and Exoskeleton Student Organization are to be thanked for advising, assisting, and funding this project.