Hypertrophic Aide by Limb Occlusion to Mitigate Muscle Atrophy in Spaceflight

Team Pleiades

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BACKGROUND

On the ISS, the microgravity environment elicits a decrease in the physical stress on muscle needed to maintain everyday functionality and movement.

Figure 1: International Space Station

Long-duration spaceflight on muscle health

↑ MUSCLE DISUSE = ↓ SKELETAL MUSCLE MASS = ↑ MUSCLE ATROPHY

Weight-bearing skeletal muscles are especially susceptible to atrophy due to their larger size.

There is a decrease of 20% in the size of these muscles in the first 5-11 days of spaceflight.

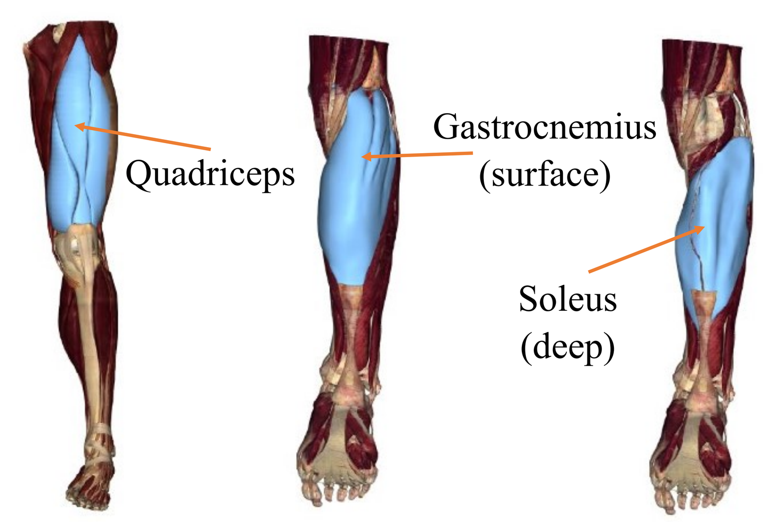


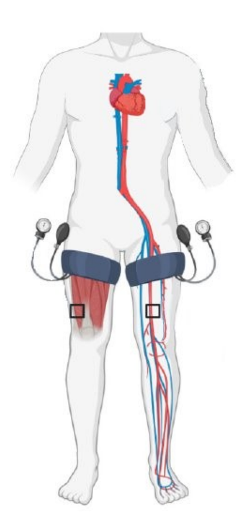
Figure 2: Lower leg musculature

Consequences

↓ MUSCLE STRENGTH = ↓ MISSION TASK PERFORMANCE = ↑ INJURY RISK

Blood Flow Restriction

Blood flow restriction is a technique that occludes blood flow to a limb by applying pressure to major local leg and arm arteries. Protocols while using this device include low intensity exercise while still mimicking the effects and benefits of high intensity exercise.



Low-Load BFR Exercise Prescription	
Description	Guidelines
Load	20-40 %1-RM
Volume	1 set x 30 reps, then 3 sets x 15 reps per exercise

Figure 3: Blood flow restriction setup and prescription

PROJECT OBJECTIVE

To address lower limb atrophy during spaceflight, we designed a compact device that allows for blood flow restriction to be implemented during resistance training to promote muscle hypertrophy and aid in muscle recovery.

DESIGN

Highlighted Components

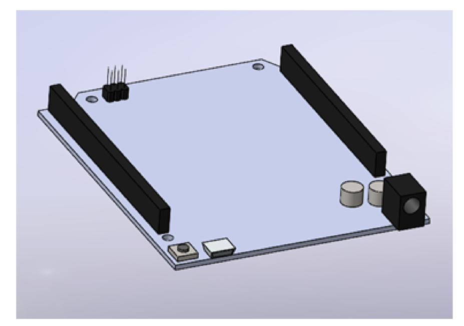


Figure 4: Microcontroller

- Function: Inflate, hold air, deflate the airbag

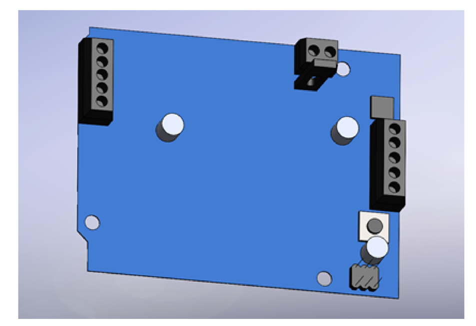


Figure 5: Motor board

- Function: Control motors

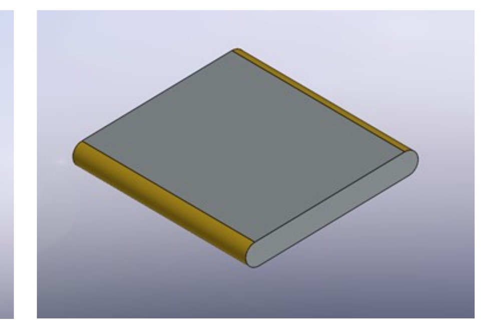


Figure 6: Battery

- Rechargeable, lithium ion

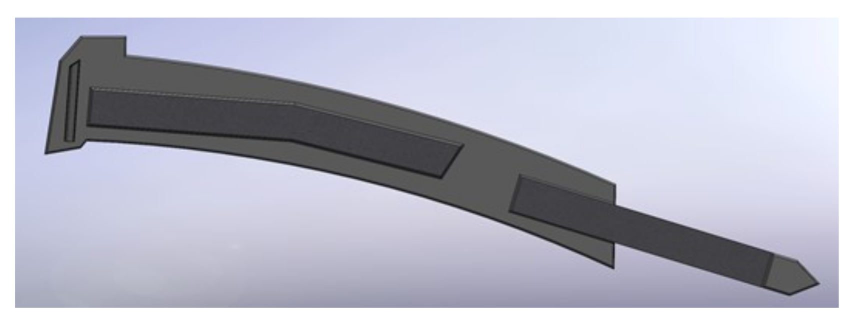


Figure 7: Cuff

- Outer layers: Nylon, spandex, polyester
- Inner layer: silver ion fabric (anti-microbial)

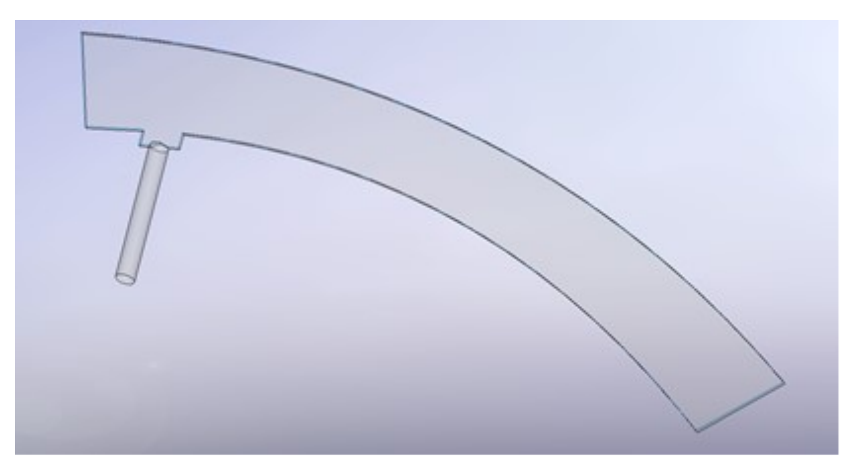


Figure 8: Airbag

- Primary Material: PVC plastic vinyl
- Adhesives: Insulation tape, other sealants
- Designed to fit within the cuff

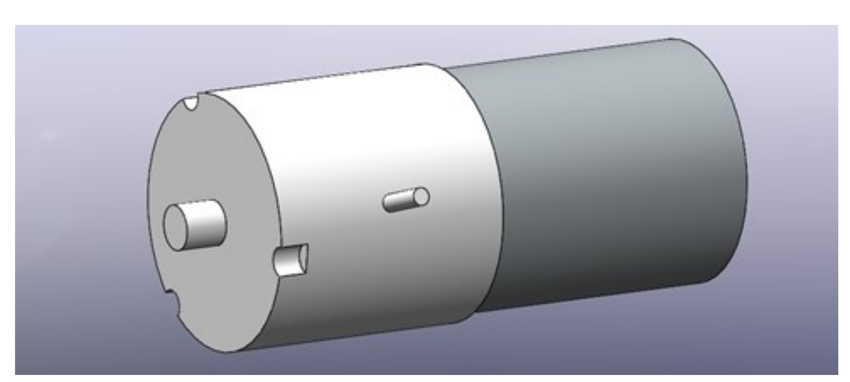


Figure 9: DC motor

- Operates at 4.5 V to allow for 2.5 L of air to pass through tubing
- 4 motors total: 2 air pumps and 2 vacuums

Hypertrophic Aide by Limb Occlusion (HALO)

Weight: 12.8 oz

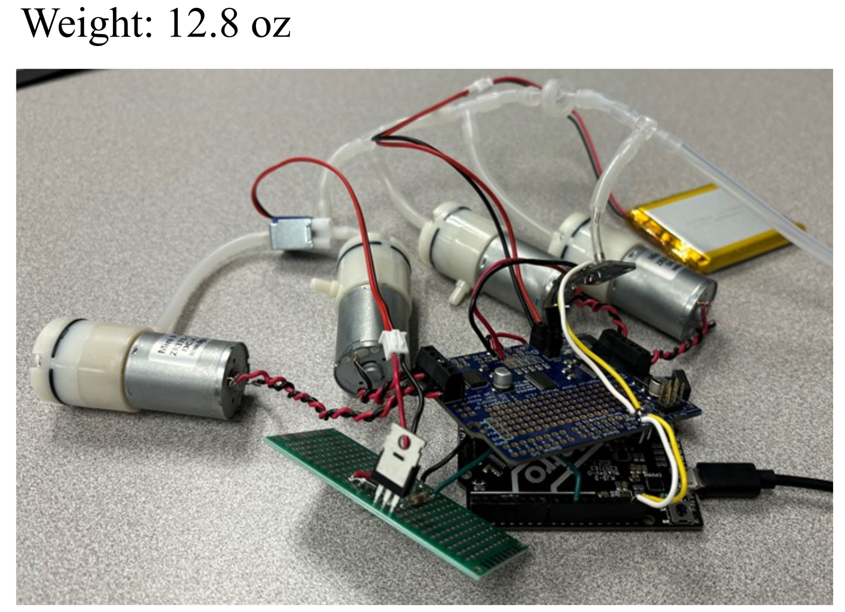


Figure 10: Electrical components of HALO

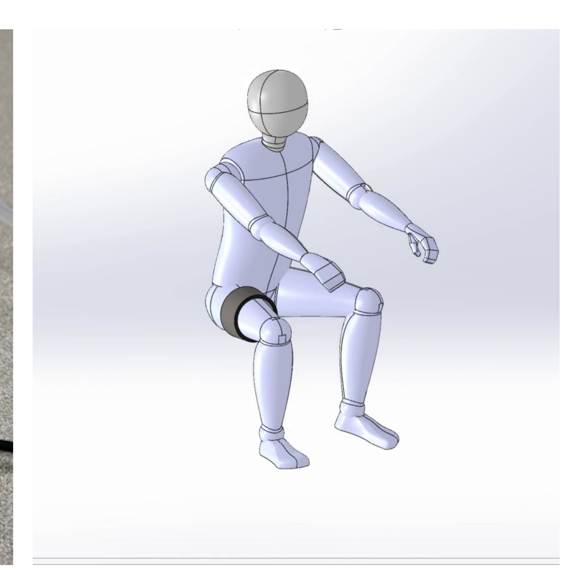


Figure 11: Placement of cuff on leg

PROGRAMMING

To code the HALO device, C++ and Arduino IDE software were used.

Goal: Inflate airbag to desired pressure

The device is programmed:

- To inflate to 145-150 mmHg (3 DC motors on motor pins 1-3)
- Maintain inflation for 15 minutes
- Deflate (1 DC motor on motor pin 4)

```
const int VALVE_PIN = 10;
const int TARGET_PRESSURE_MIN = 145;
const int TARGET_PRESSURE_MAX = 150;
const int MAX_INFLATE_TIME = 15 * 60 * 1000;
const int HOLD_DURATION = 15 * 60 * 1000;
const int RESET_DURATION = 10000;

Adafruit_MPRLS pressureSensor = Adafruit_MPRLS(RESET_PIN, EOC_PIN);
Adafruit_MotorShield AFMS = Adafruit_MotorShield();
Adafruit_DCMotor *inflate1 = AFMS.getMotor(1);
Adafruit_DCMotor *inflate2 = AFMS.getMotor(2);
Adafruit_DCMotor *inflate3 = AFMS.getMotor(3);
Adafruit_DCMotor *deflate1 = AFMS.getMotor(4);

unsigned long inflateStartTime = 0;
unsigned long holdStartTime = 0;
unsigned long lastUpdateTime = 0;
bool inflating = false;
bool holding = false;

float atmosphericPressure = 0.0;
float gaugePressure = 0.0;
```

TESTING RESULTS: EXERCISE

Protocol

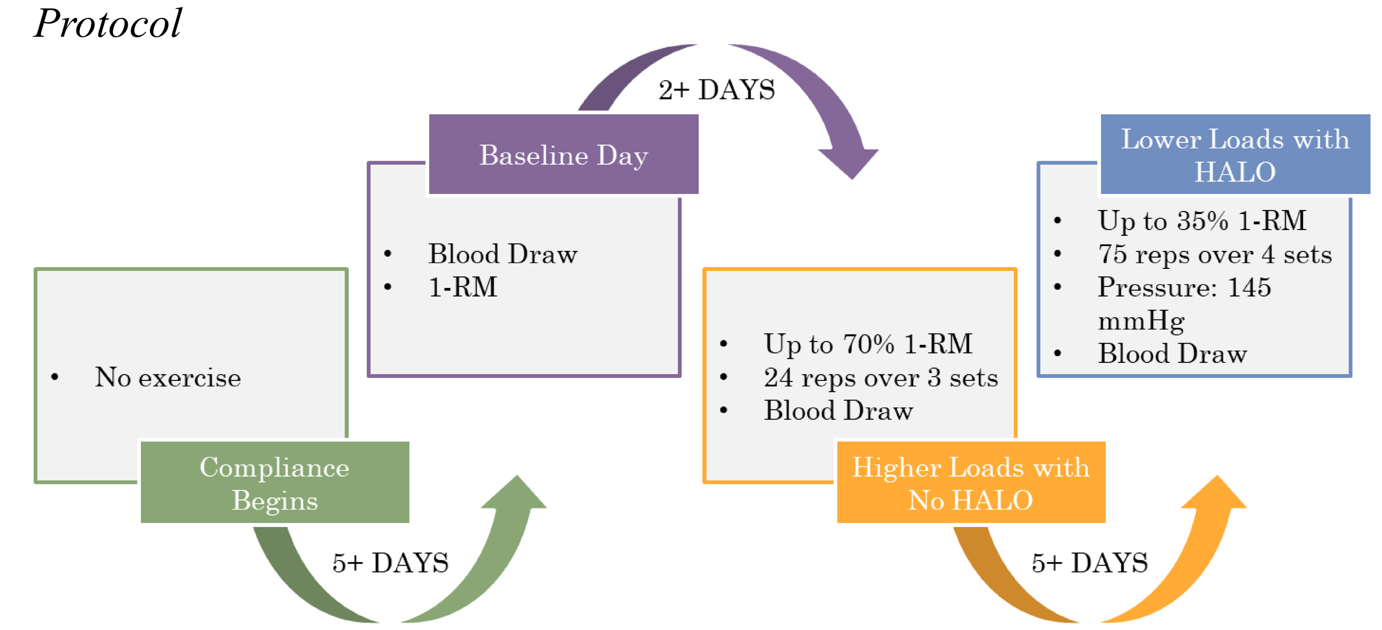


Figure 12: Protocol timeline. HALO: Hypertrophic Aide by Limb Occlusion.

Exercises

- Back squat
- Romanian deadlift
- Deadlift
- Single-leg heel raise
- Single-leg knee extension

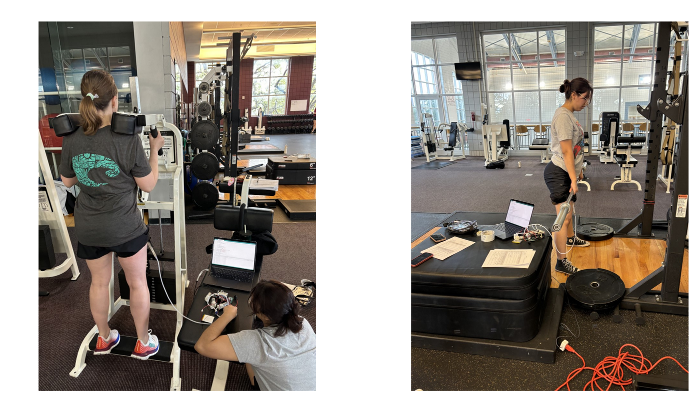


Figure 13: Exercise setup examples

Vascular Endothelial Growth Factor Concentrations

With blood samples, levels of vascular endothelial growth factor (VEGF) were measured. VEGF:

↑ ANGIOGENESIS

and

↑ CIRCULATION

and

↓ ARTERIAL STIFFNESS

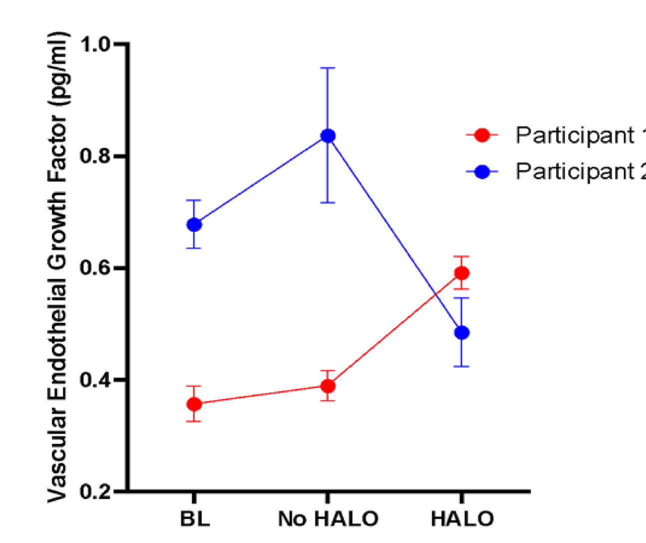


Figure 14: VEGF levels vs. Time

There was a 41.4% increase and 53.2% decrease, in VEGF from exercise without the HALO to exercise with the HALO in participants 1 and 2, respectively. Inter-individual responses to exercise are therefore evident.

TESTING RESULTS: PRESSURE

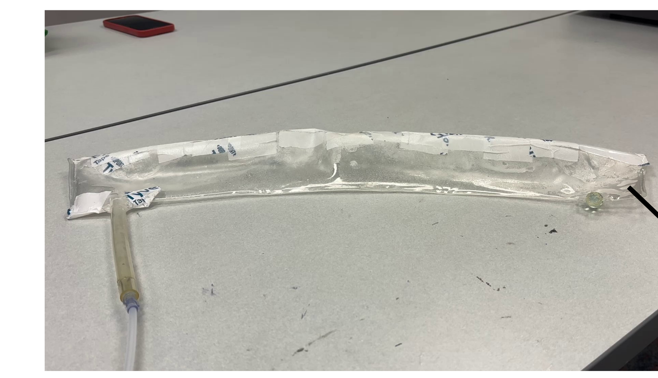


Figure 15: Deflated airbag

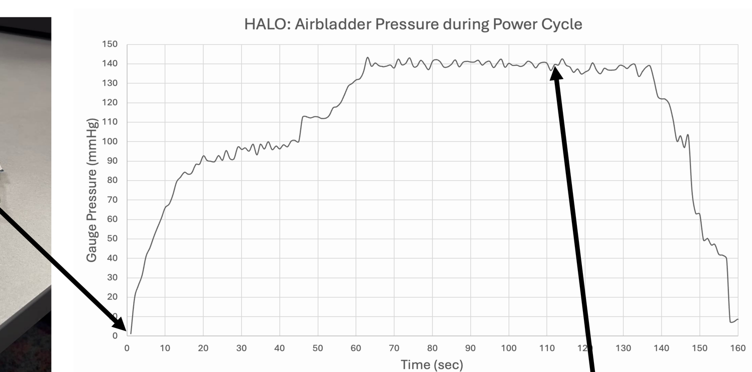


Figure 16: Cuff pressure vs. Time

When the airbag is deflated, the pressure reads 0 mmHg. When inflated, the pressure is approximately 140 mmHg. There is a slight delay in the time to reach the peak pressure due to the DC motor performance at that point.

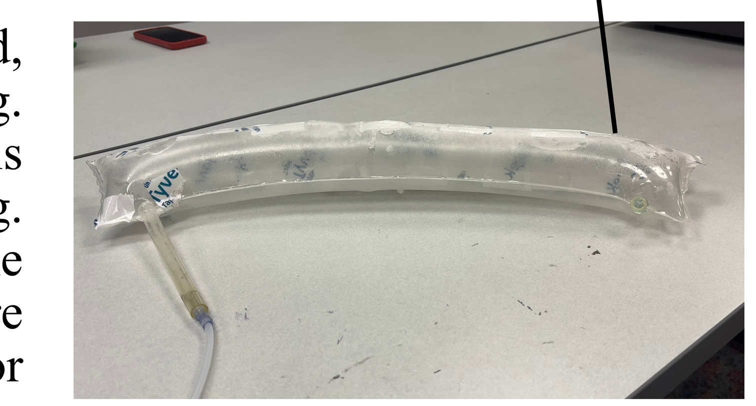


Figure 17: Inflated airbag

TRAINING WITH HALO VS. NO HALO

	Resistance Training without HALO	Resistance Training with HALO
Muscular Hypertrophy	High with heavier weight	High with lower weights
Set and Repetition Consistency	Less predictable	Standardized
Joint Stress	Higher	Lower
Recovery Time	Longer	Shorter
Session Time	Longer and less predictable	Shorter and predictable

Figure 18: HALO: Hypertrophic Aide by Limb Occlusion.

FUTURE DIRECTIONS

- Incorporation of an increased power supply to reduce inflation time
- Implementation of an individualized arterial occlusion pressure
- Exploration of other materials to increase durability of air bladder
- Creation of an additional blood flow restriction cuff

CONCLUSION

We designed, fabricated, and tested the HALO device, which provides blood flow restriction during resistance exercise in spaceflight.

ACKNOWLEDGMENTS

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QUESTIONS AND REFERENCES

All questions can be sent to the team lead Erin Rocha at erocha@twu.edu.

All references can be found by scanning the QR code to the right.