# Mitigating Shoulder Injuries During Long-Duration Spaceflight

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## PROJECT OBJECTIVE

To address the issue of shoulder injuries in long-duration spaceflight, we developed a device targeting the rotator cuff muscles as a supplementary tool with current exercise prescriptions for astronauts to decrease the risk of rotator cuff injuries during performance of extravehicular activities (EVAs).

## BACKGROUND

- The **glenohumeral (GH) joint** of the shoulder is a ball-and-socket joint that allows high mobility but low stability.
- The **Hard Upper Torso (HUT)** of the **Extravehicular Mobility Unit (EMU)** restricts movement and negatively alters shoulder mechanics.
- **EVAs** require repetitive movements, overhead tasks, and constrained working positions.



Figure 1: The GH joint restricted by the HUT



Figure 2: Astronaut Performing EVAs

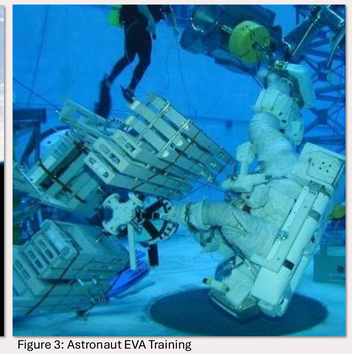


Figure 3: Astronaut EVA Training

## SHOULDER INJURY

- Shoulder injuries are the second most reported injury in microgravity.
- 64% of 22 surveyed astronauts reported shoulder pain associated with EMU training.
- 35% of surveyed EVA astronauts experienced shoulder injuries.

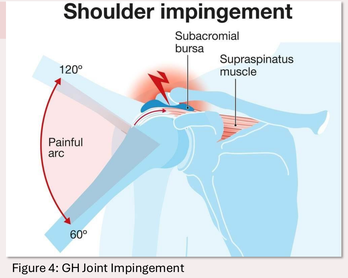



Figure 4: GH Joint Impingement

Ball-and-Socket Joint → ↓ Stability → ↑ Risk of Injury

↑ Muscle Strength → ↑ Stability → ↓ Risk of Injury

## DESIGN

### ASTER

ASTER is designed to provide adjustable resistance targeting the rotator cuff muscles by using an electromagnetic solenoid on a ferromagnetic steel surface. Increasing the current supplied to the solenoid increases its magnetism. The handle is ergonomically designed at a 20° angle to reduce strain on the wrist. LEDs along the top of the board help track which set of exercise to perform.



Figure 5: ASTER Ergonomics

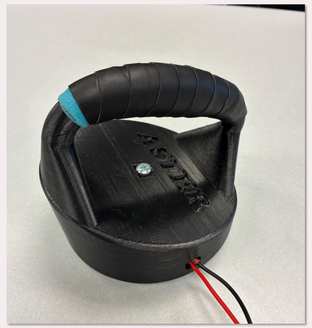


Figure 6: ASTER

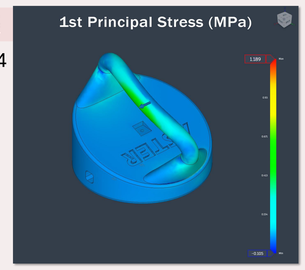
### FINITE ELEMENT ANALYSIS

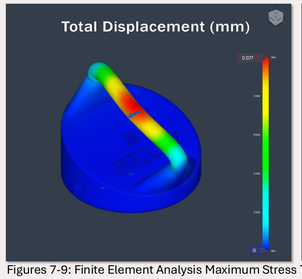
Static stress test with 44 Newtons of force (10 pounds)

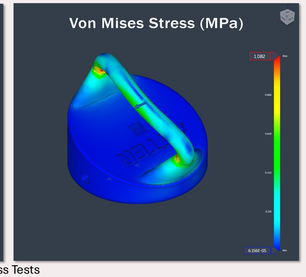
**Von Mises** maximum stress:
- 1.082 MPa

**1st Principal** maximum stress:
- 1.189 MPa

**Total Displacement**:
- 0.077 mm




Figures 7-9: Finite Element Analysis Maximum Stress Tests

### PROGRAMMING

- A CRICKIT M0 reads the dial position and converts the selected resistance level into a PWM value.
- The PWM signal controls a MOSFET driver, which changes current level from the 5V battery to the solenoid allowing for adjustable magnetic resistance.

```
if (digitalRead(LEVEL_1) == LOW)
  power = 128;    // 50%
else if (digitalRead(LEVEL_2) == LOW)
  power = 170;    // 66.67%
else if (digitalRead(LEVEL_3) == LOW)
  power = 212;    // 83.33%
else if (digitalRead(LEVEL_MAX) == LOW)
  power = 255;    // 100%

analogWrite(MOSFET_PIN, power);
```

Figure 10: Code Sample

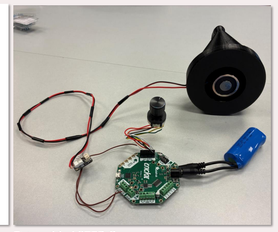


Figure 11: ASTER Components

## TESTING METHODS



Figure 12: BIODEX Joint Torque Assessment

**Internal Rotation Torque** of the glenohumeral joint was measured using the BIODEX while participants maintained 90° of shoulder abduction and 90° of elbow flexion.

**Electromyography (EMG)** measures the electric action potential of the muscle belly. Sensors were placed facing the GH joint on the:
- Anterior Deltoid
- Posterior Deltoid
- Pectoralis Major (sternocostal head)

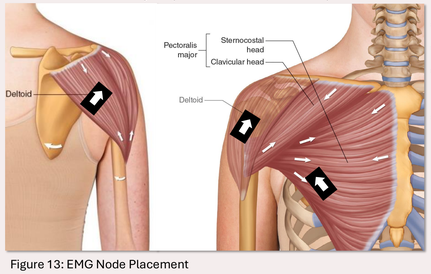



Figure 13: EMG Node Placement

### EXERCISE PROGRAM

**Prescription**
- ~35 minutes total
- 5-minute dynamic warm-up
- 3 sets per arm
- 45 seconds per set
- Alternate arms between sets
- Four exercises
  - Circles: clockwise, counterclockwise
  - Zig-zags
  - ABCs
- 3-minute rest between exercises

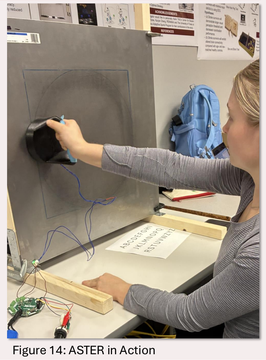
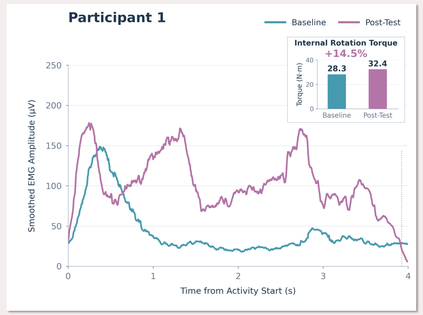


Figure 14: ASTER in Action

## TESTING RESULTS

### EMG with Internal Rotation Torque (Nm)



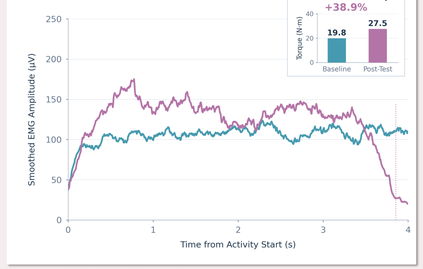




Figure 15: EMG & Joint Torque Graphs

Participants performed a maximal internal rotation isometric hold for four seconds in order to quantify torque of the anterior deltoid muscle.

- After two weeks of training, internal rotation torque was increased in both participants.
- Participant 1 increased maximal torque by 14.5%.
- Participant 2 increased maximal torque by 38.9%.
- EMG amplitude was generally higher during early and middle portions the of contractions.
- More sustained activation was observed across both trials.

## CONCLUSION

ASTER effectively strengthened & activated the rotator cuff musculature and may therefore mitigate shoulder injuries during long-duration spaceflight by improving dynamic stability of the GH joint.

## FUTURE DIRECTIONS

- Component housing group within the handle for wireless use
- More levels of resistance for increased individuality
- LED screen that displays exercise program & time

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REFERENCES