Supplementing Biomechanical Modeling with EMG Analysis

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Problem Statement

• Given the small size of the Multi-Purpose Crew Vehicle (MPCV) exercise device, will it be able to provide sufficient physiological loading to maintain musculoskeletal performance?

• Advanced Exercise Concepts Project Risk:
  – (EM2ED-003) The single-strap design will not allow for exercises to be performed as specified in the functional requirements document (AEC-REQ-001)

• Advance Exercise Concepts Project Requirement:
  – [MPCV-AEC29] Required Resistive Exercises: the device shall allow the crew member to perform squat, deadlift and heel raise exercises with proper body positioning (according to JSC-29558, “Resistive Exercise Description Document”)

• OpenSim biomechanical modeling performed to inform risk mitigation
Biomechanical Models in OpenSim

- OpenSim is open source biomechanical simulation software (https://simtk.org/home/opensim)
  - For development of musculoskeletal models
  - For dynamic simulations of movement and kinematics
  - For estimating muscle and joint kinetics

- DAP uses a modified version of the Arnold (2010) lower body model (Gallo, 2016)

- Biomechanical modeling process
  - Experimental kinematic and kinetic data used as input
  - OpenSim biomechanical models used to estimate joint torques and muscle forces

EMG Supplementing Biomechanical Modeling

• EMG – Electromyography – A record of the electrical potential generated by activated muscle cells

• EMG data will be used to increase the credibility of the OpenSim models
  – Through validation of calculated muscle activity
  – By increasing the input data pedigree

• Data use within OpenSim:
  – As constraints in the calculation of muscle activity
  – As input data instead of calculated muscle activity
EMG System in the GRC Exercise Countermeasures Lab

- BTS Free EMG 300
- 16 wireless sensor system
- Smart Capture/Analyzer and EMG Analyzer software
- Muscles recorded:
  - Tibialis Anterior
  - Vastus Medialis
  - Rectus Femoris
  - Vastus Lateralis
  - Hip Adductor
  - Rectus Abdominis
  - External Obliques
  - Medial Gastrocnemius
  - Lateral Gastrocnemius
  - Semitendinosus
  - Biceps Femoris
  - Gluteus Maximus
  - Multifidus
  - Longissimus
  - Middle Trapezius
  - Upper Trapezius
EMG Data Collection Procedure

- Muscles active during each exercise were selected for recording and verified with a literature search.

- Sensor location determined from [http://seniam.org](http://seniam.org) and the Thought Technology Ltd. surface EMG placement guide.

- Signal strength was verified to determine correct sensor placement.
Maximum Voluntary Contraction

- EMG collected during ~5s Maximum Voluntary Contraction (MVC) for each muscle

- Muscle produces maximum force during isometric, 0 velocity contractions

- MVC used to normalize EMG signals from exercise trials

Test Variables

Exercises
- Squat (SQ)
- Deadlift (DL)
- Heel Raise (HR)
- Single-leg squat (SLS)

Loading Configurations
- Free weight
- Long bar
- Yo-yo Harness (SQ, HR, SLS)
- T-Bar (DL, HR)
- Glenn Harness

Stance Variation (Controlled with foot markings)
- Shoulder width (SQ)
- Restricted to 21” (SQ)
- Hip width (DL)
- Sumo (DL)
- Toes pointed in (HR)
- Toes pointed out (HR)
- Free foot forward (SLS)
- Free foot back (SLS)

External Load
- Body Weight
- Low – 10-12 rep max load
- Medium - 6-9 rep max load
- Heavy – 3-5 rep max load

Cadence (Controlled with metronome)
- 4s (SQ, DL, SLS)
- 2.5s (SQ, DL, SLS)
- 2s (HR)
- 1s (HR)

Exercises performed according to JSC 29558, Resistive Exercise Description Document and an experienced athletic coach monitored subject form
Variables Compared in this Presentation

• Compare EMG time course and amplitude between different test cases
  – Deadlift
    • Free weight
    • HULK one-point loading with T-bar
  – Squat
    • Free weight
    • HULK one-point loading with Yo-yo harness
EMG Data Processing Procedure

- DC component removal and bandpass filter (20 – 450 Hz)
- Rectify and envelop signal with RMS calculation, using a 250 ms window
- Normalize to MVC
- Break signal into repetitions
- Determine the time-normalized, average repetition, with a ± standard error band around the average
- Determine average, peak and integrated EMG for each repetition

Results - Squat

- Gluteus Maximus
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time

- Vastus Lateralis
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time

- Rectus Femoris
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time

- Hip Adductors
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time

- Longissimus
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time

- Tibialis Anterior
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time

- Medial Gastrocnemius
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time

- Lateral Gastrocnemius
  - Free Weight
  - HULK and Yo-yo Harness
  - Normalized Rep. Time
Summary Graphs - Squat

Mean Activation Squat

Peak Activation Squat

iEMG Squat

FRWT  YHAR

FRWT  YHAR
Results - Deadlift

- **Gluteus Maximus**
- **Vastus Medialis**
- **Rectus Femoris**
- **Hip Adductors**
- **Longissimus**
- **Tibialis Anterior**
- **Medial Gastrocnemius**
- **Lateral Gastrocnemius**

**Muscle Activation**

- **Free Weight**
- **HULK and T-Bar**

Normalized Rep Time
Summary Graphs - Deadlift

Mean Activation Deadlift

Peak Activation Deadlift

iEMG Deadlift
Discussion

• Differences in muscle activation observed when exercise is performed with free weights vs. a single-strap exercise configuration

• Limitations with EMG analysis
  – Only one subject used
  – EMG data collected across days
  – MVC not achieved in all cases

• Differences should be explored further to determine their significance
  – Through the full biomechanical analysis currently underway
  – Through a review of the results by subject matter experts

• The full biomechanical analysis is informing the AEC project risk by providing a means of early evaluation
Thank you

Questions?