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 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

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

- 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)

- 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

- Piitulainen et al., Multi-channel electromyography during maximal isometric and dynamic contractions, J Electromyogr Kinesiol, 23, 302-310, 2013.
Results - Squat

Gluteus Maximus

Vastus Lateralis

Rectus Femoris

Hip Adductors

Longissimus

Tibialis Anterior

Medial Gastrocnemius

Lateral Gastrocnemius

Free Weight

HULK and Yo-yo Harness
Results - Deadlift

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

Free Weight
HULK and T-Bar
Summary Graphs - Deadlift

Mean Activation Deadlift

Peak Activation Deadlift

iEMG Deadlift

FRWT  TBAR
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?