



1. BACKGROUND

- Prior research was aimed at analyzing and decomposing 2-digit finger forces while changing object properties such as mass and torque
- The conclusions were that manipulation force (FM) is modulated throughout object lift onset and stability of the object is prioritized [1]
- Grasp force (FG) functions as a feedforward mechanism, and is not modulated, but remains constant at object grasp
- Grasp force is much larger than what is minimally biomechanically obligatory for a stable grasp

2. STUDY AIM

Determine the effects of task requirements on the coordination of grasp and manipulation forces, specifically focusing on object fragility by imposing task constraints.

3. METHODS

- Inverted T-block is used to measure thumb and finger forces
- High-density EMG is connected via 4 arrays for Flexor, Extensor, Thumb, and Finger Muscles
- Conditions are imposed to constrain FG

Fragility High

- Subject imagines object is like an egg, and will "break" if grasped too hard
- FG is much lighter

^y∫ x

- **Fragility Low** Subject must meet FG
- threshold before lifting up object by pressing harder with both fingers
- FG is much harder

• G₀ represents the null space of G

Manip Forc

 \hat{z}^{10}

 $\widehat{\mathsf{Z}}$

_ 200

Effects of Object Fragility on Digit Force **Coordination for Manipulation**

Samuel F. Ramos, Yen-Hsun Wu, and Marco Santello School of Biological and Health Systems Engineering, Arizona State University, Tempe, AZ USA

4. MANIPULATION AND GRASP FORCE DECOMPOSITION

Digit Force Decomposition

Grasp $\overrightarrow{F}_{G} = G_{0}G_{0}^{T}\begin{bmatrix} \overrightarrow{T}_{H} & \overrightarrow{I}_{N} \end{bmatrix}^{T}$ **Force (F_G)** $\overrightarrow{F}_{G} = G_{0}G_{0}^{T}\begin{bmatrix} \overrightarrow{F}_{C} & \overrightarrow{F}_{C} \end{bmatrix}^{T}$

Solution
$$\vec{F}_M = \begin{bmatrix} \vec{F}_H & \vec{F}_N \end{bmatrix}^T - \vec{F}_G$$

• $\vec{F}_C^i = \begin{bmatrix} f_X & f_y & f_z & m_z \end{bmatrix}^T$ represents the contact force



5A. RESULTS



Figure 2. Manipulation force and grasp force for Right Distal – Fragility High Condition of 20 successful trials for 1 representative subject.







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5B. RESULTS



Figure 5. Mean values of FG and FM during Hold and Lift for all Right Distal Conditions for 1 representative subject.

6. CONCLUSIONS

- Subjects are able to successfully complete task requirements with minimal exposure to experimental conditions
- Subjects are able to maintain grasp stability under different constraints without modulation of manipulation force

7. FUTURE AIMS

- Continue to collect additional subject data
- Analyze EMG data and observe the effects of different FG constraints
- Compare general trends across subjects for both FG and FM

8. REFERENCES

[1] Wu, Y.-H. 2023. Scientific Reports, 13(1), 12037.

[2] Murray, R. M. 1994. A Mathematical Introduction to Robotic Manipulation (1st ed.). CRC Press

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