# The Effect of Splenius Capitis Fatigue on Load Sharing in the Cervical Extensors

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# Acknowledgements


- I would like to thank my co-author Dr. Constantin M. Heinemann

- This work was supported by Office of Naval Research (N000142112649) and by the East Carolina University Department of Kinesiology.

# Disclosure

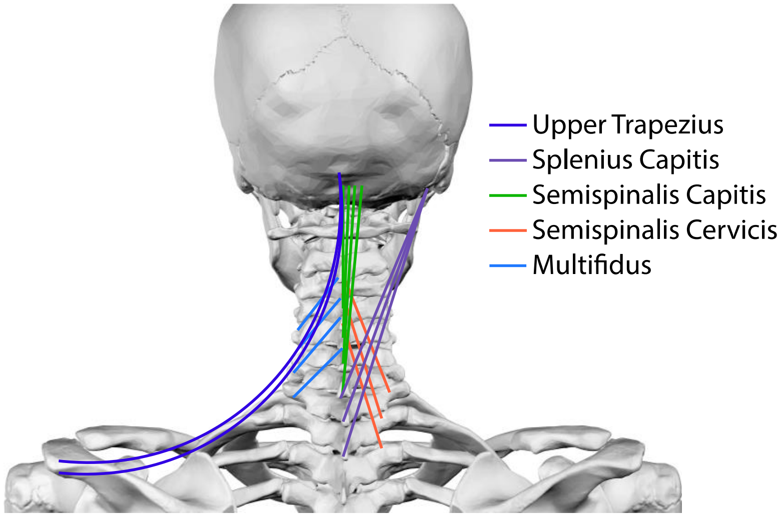
- I have no conflicts to report

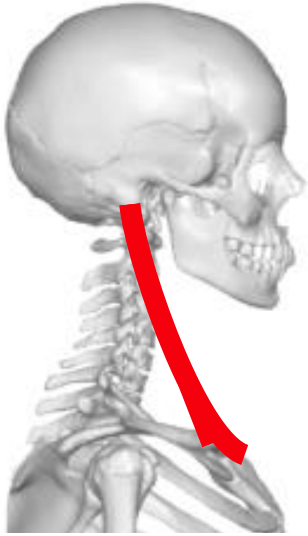
# Flight Helmets Worn by Pilots

- Fighter pilots don helmet systems which allow for great operational awareness and maneuverability
- Helmets impart heads up display on the visor which displays
    - Flight information
    - Navigation cues
    - Targeting information
    - And other flight related information (Li et al., 2013)
- The optical elements which allow this apply a mass to the front of the head increasing the applied external flexion moment (Li et al., 2013)

# Flight Impact on Neck

- Flight helmets are associated with changes in muscle activity
  - Higher activity during simulated flight (Murray et al 2016, Sovelius et al 2020)
  - Decrease in EMG median frequency cycles Le et al. 2023
- Non-neutral head positions are associated with higher neck muscle activity during flight (Sovelius et al. 2020)



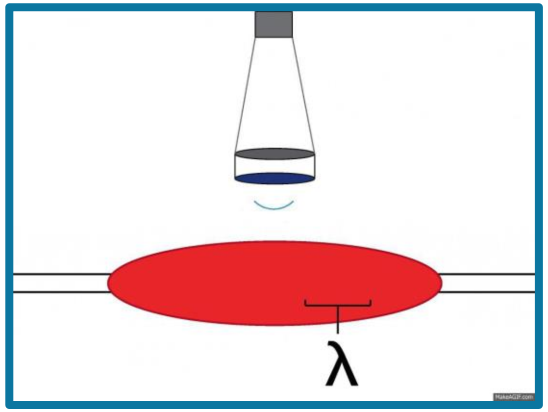



# Flight Impact on the Neck

- The sustained muscular demands required to stabilize the head/neck system under helmet loading predispose fighter pilots to cervical muscle fatigue.
- Muscle fatigue diminishes its force producing capability and therefore can change how load is shared among CE; this may expose a muscle to overloading and impact the joint reaction forces in the cervical spine.

# Shear Wave Elastography

- Ultrasound shear wave elastography (SWE)
  - Traditionally used to quantify shear modulus
  - Both valid (Eby et al., 2013) and reliable (Seymore, Domire, DeVita, Rider, & Kulas, 2017) in muscle
  - Superficial and deep neck musculature can be assessed (Dieterich et al., 2016).
  - Able to identify areas of increased muscle stiffness that are associated with pain (Chen et al., 2016).
- Shear wave velocity is also modulated by tension in tissue the relationship between shear wave velocity (c), shear modulus (μ) and stress (σ) can be expressed as:




$$c^2 = \frac{\mu k' + \sigma}{\rho}$$

Where ρ – Tissue density
k' – shear correction factor

# Purpose

- Fatigue reduces the force producing capacity of a muscle
- The purpose of this study was to assess cervical extensor load sharing before and after fatigue targeting splenius capitis across multiple head postures and with a flight helmet
- This study examined how fatigue of one muscle within the CE alters loading and puts forth a paradigm for examining fatigue related changes in load sharing

# Methods

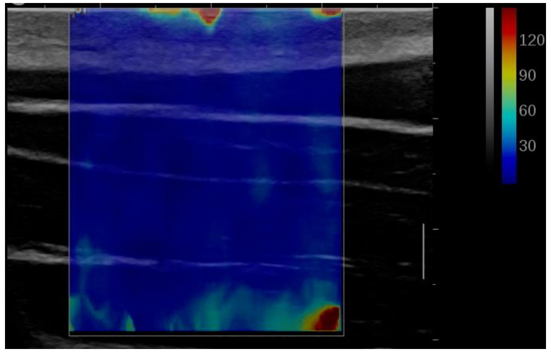
- 20 Healthy Young participants

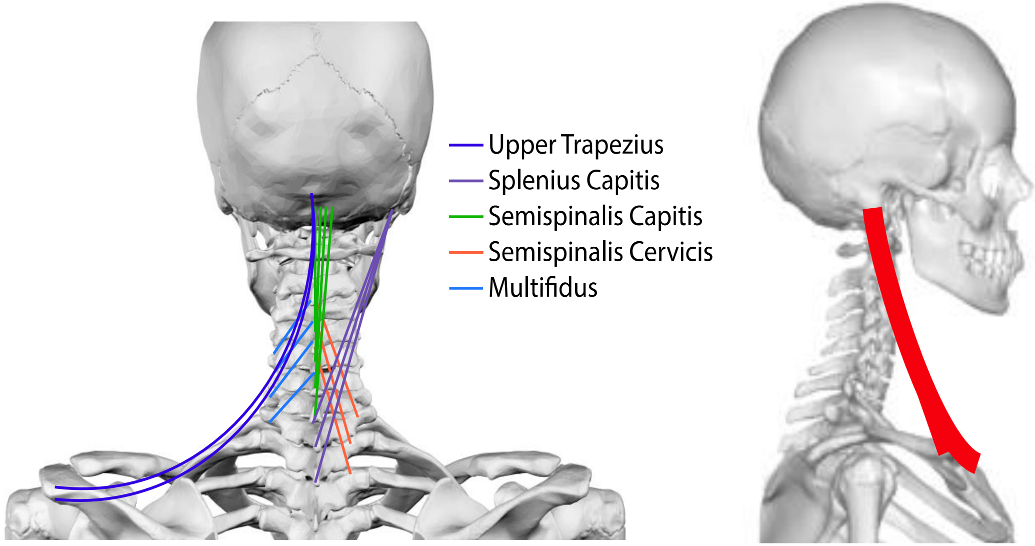
- Participants were imaged in several conditions
  - Prone
    - Resting
    - 20% Neck extension
  - Seated
    - Neutral
    - Looking down
    - Turned
    - ‘Check Six’

- Participants with three head supported mass
  - No helmet (NH)
  - Fighter helmet weight facsimile (FH).

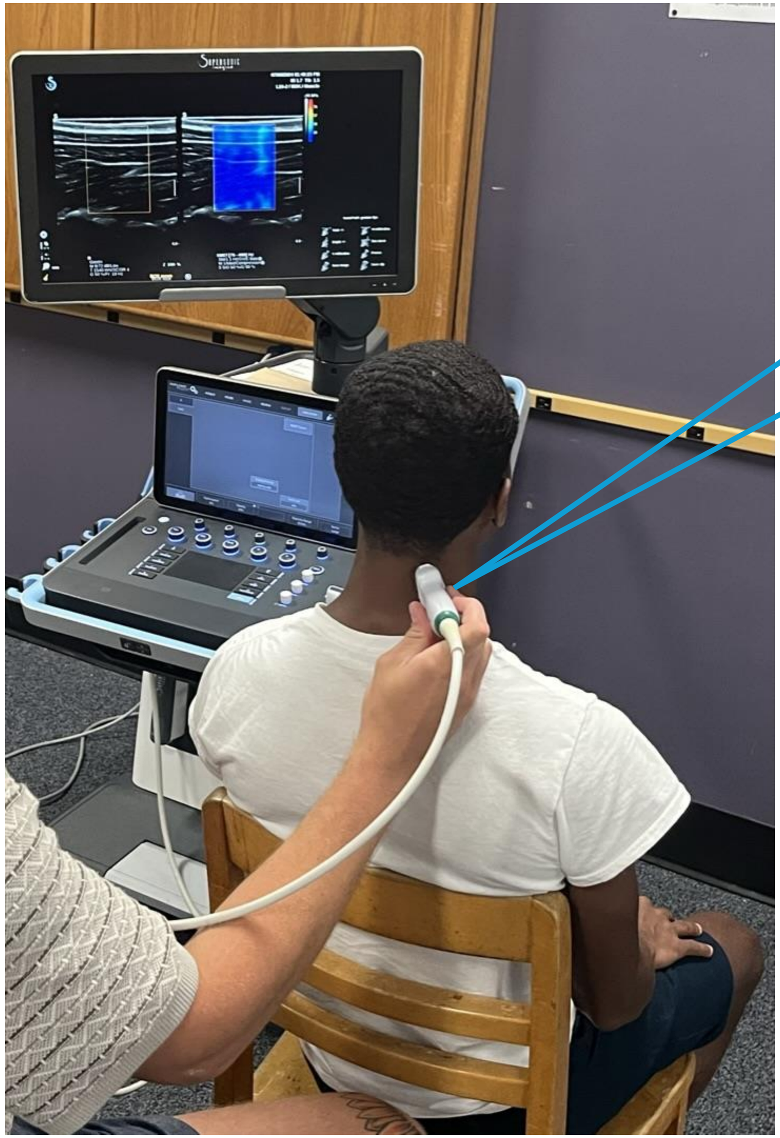
# Methods

- Shear wave elastography images were taken of the cervical muscles
    - Cervical Trapezius
    - Splenius Capitis
    - Semispinalis Capitis
    - Semispinalis Cervicis
    - Multifidus



# Shear Wave Elastography to Force



$$c^2 = \frac{\mu k' + \sigma}{\rho}$$

In muscle

$$c^2 = \mu + \sigma$$

or

$$\sigma = \mu - c^2$$

c = Shear wave speed

$\mu$ = Shear elastic modulus

$\sigma$ = Muscle stress

k = Correction factor

$\rho$ = Tissue density

With muscle CSA

$$\underline{F} = \sigma \times CSA$$

# Fatiguing Protocol

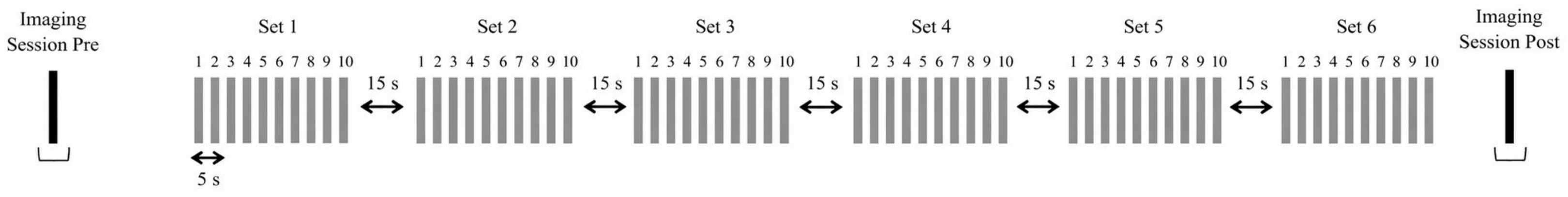
Unilateral axial rotation to either left or right

6 sets × 10 repetitions

Each repetition was 5 seconds of maximum isometric axial rotation of the head

Reps were separated by 5 seconds of rest

Sets were separated by 15 seconds of rest

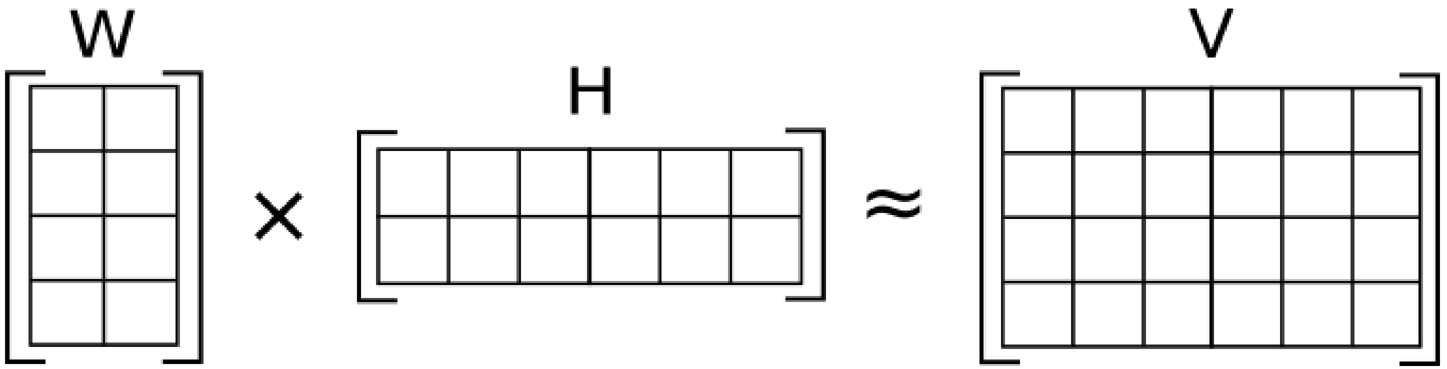





21. Siracusa et al., 2019 22. Chalchat et al., 2020

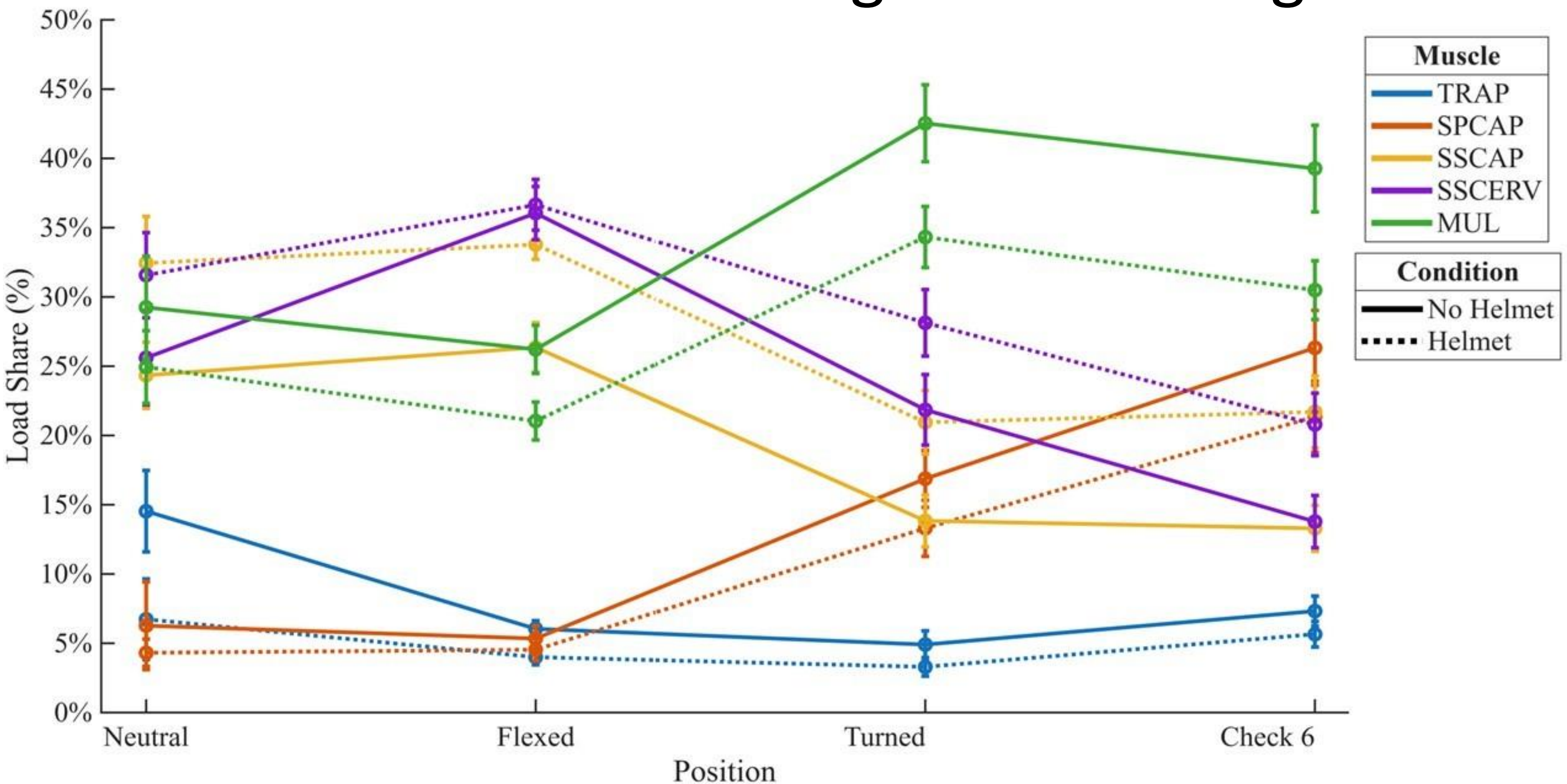
# Nonnegative Matrix Factorization

- Nonnegative matrix factorization
  - $V = W \times H$
    - V: Muscle-by-observation matrix
    - W: Synergy weights
    - H: Activation coefficient
  - Changes in synergy activation were analyzed to assess fatigue related coordination changes.



# Results: Muscle Force

- Splenius capitis force was significantly reduced during isometric extension and across seated postures
- No other CE reached significant change following fatigue



# Results: Nonnegative Matrix Factorization

- Two synergy solution was chosen ($R^2$=0.827)
  - Substantial improvement from one ($R^2$=0.68)
  - Additional synergies
    - Minimal gains in reconstruction
    - Single muscle dominated or redundant patterns
- W1: Global Extensor Synergy
  - CT, SSCAP, SSCER, MUL
- W2: Rotator Specific Synergy
  - SPCAP, MUL

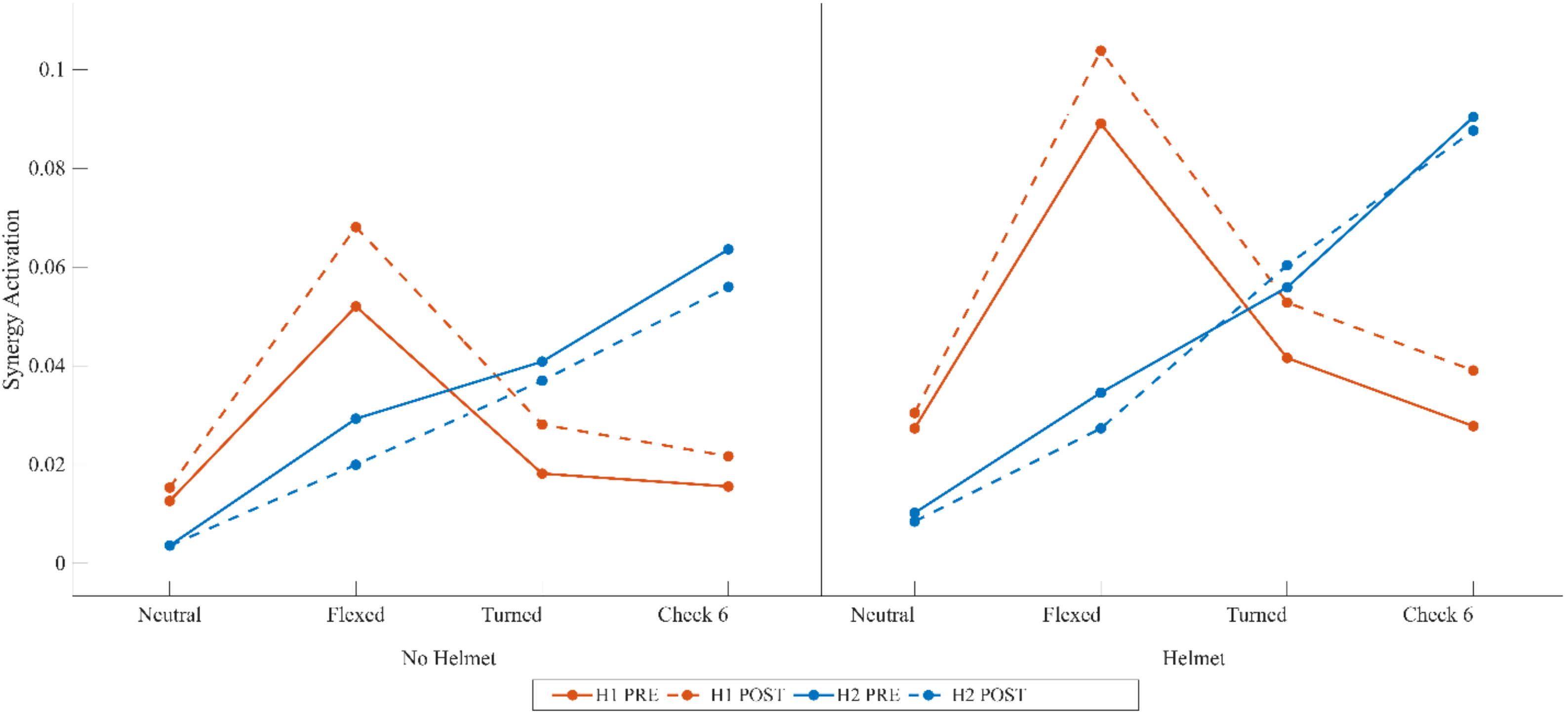
| Muscle | W1 | W2 |
|---|---|---|
| CT | 19% | 10% |
| SPCAP | 3% | 48% |
| SSCAP | 20% | 1% |
| SSCER | 21% | 3% |
| MUL | 36% | 38% |

# Results: Activation Coefficient Analysis

- Helmet
  - H1 ↑
  - H2 ↑
  - Increased H1 more than H2

- Posture
  - – H1 more active in sagittal plane
  - – H2 more active in rotated postures

- Fatigue
  - – H1 ↑
  - – H2 ≈
  - – Shift towards global extensor



# Conclusion

- Fatigue → system-level amplification, not muscle-specific substitution
- Increased demand on deep stabilizers
- Synergies capture coordination-level adaptations missed by individual muscle analysis
- Useful for understanding fatigue under helmeted flight conditions

# Thank you!

# Questions?