Muscle Co-contraction in Lower Extremities
First Step Towards a Wearable Skin to mitigate them

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INTRODUCTION

- Osteoarthritis (OA) is a degenerative disease that affects over 30 million adults in the US alone [1].
- Higher-than-normal joint contact forces are a contributor to OA onset and progression [2, 3].
- Excessive muscle co-contractions can increase joint contact forces [4].
- Muscle co-contraction occurs when counteracting muscles activate simultaneously.

Study goal: quantify the amount of co-contractions in the thigh and leg muscles during gait for healthy subjects.

Long-term goal: develop a wearable skin to mitigate excessive co-contractions and minimize the risk of OA onset and progression.

METHOD

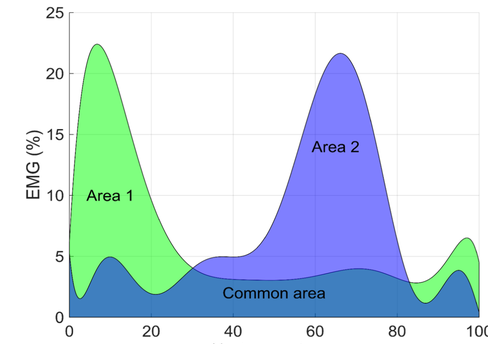
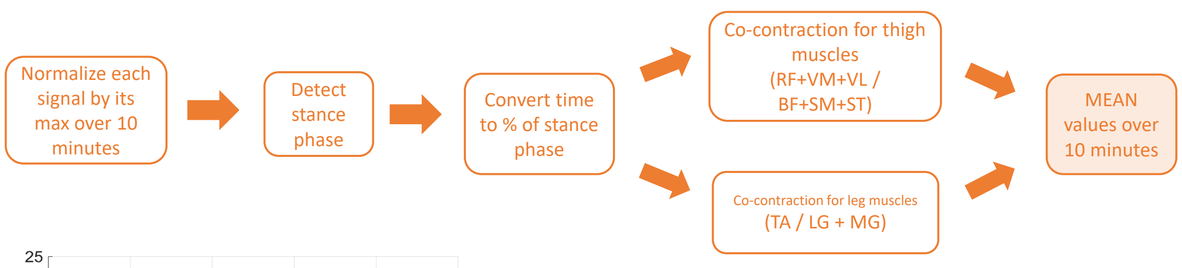


Figure 1. Thigh and leg muscle signals recorded

Data collection protocol (IRB-approved):
- 17 subjects: 10 males, 7 females
- Age: 18-25 years old
- 10-minute gait trial on an instrumented treadmill

Measurements:
- Muscle activity (EMG): electrodes on 16 muscles
  - Thigh muscles: Rectus Femoris (RF), Vastus Lateralis (VL), Vastus Medialis (VM), Biceps Femoris (BF), Semimembranosus (SM), Semitendinosus (ST)
  - Leg muscles: Tibialis Anterior (TA), Medial and Lateral Gastrocnemius (MG and LG, respectively)
- Kinematics: 32 motion analysis markers (Rizzoli lower body protocol)
- Pressure distributions under the feet

EMG Signal post-processing:
- EMG post processing: Bandpass 40 – 400Hz > Rectification > RMS Smoothing 50ms
- Co-contraction calculation (per subject and per right gait cycle) [5]:



$$\text{Co-contraction} = 100 * \frac{2 * common\ area}{Area\ 1 + Area\ 2}$$

Figure 2. Areas used to compute the co-contraction

RESULTS

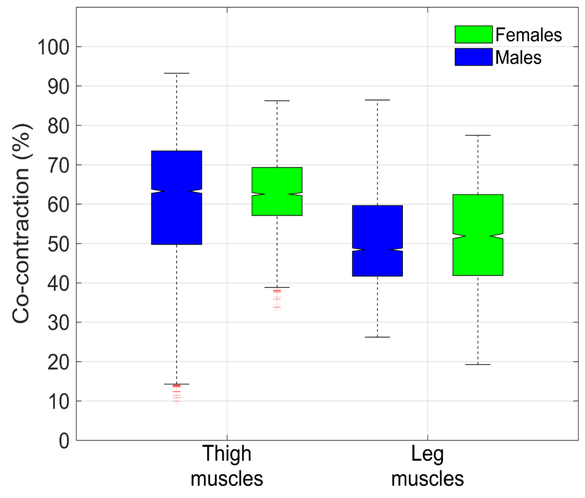


Figure 3. Mean co-contraction over the 10-minute gait trial: a) thigh muscles, b) leg muscles. Outliers are outside of ±1.5IQR.

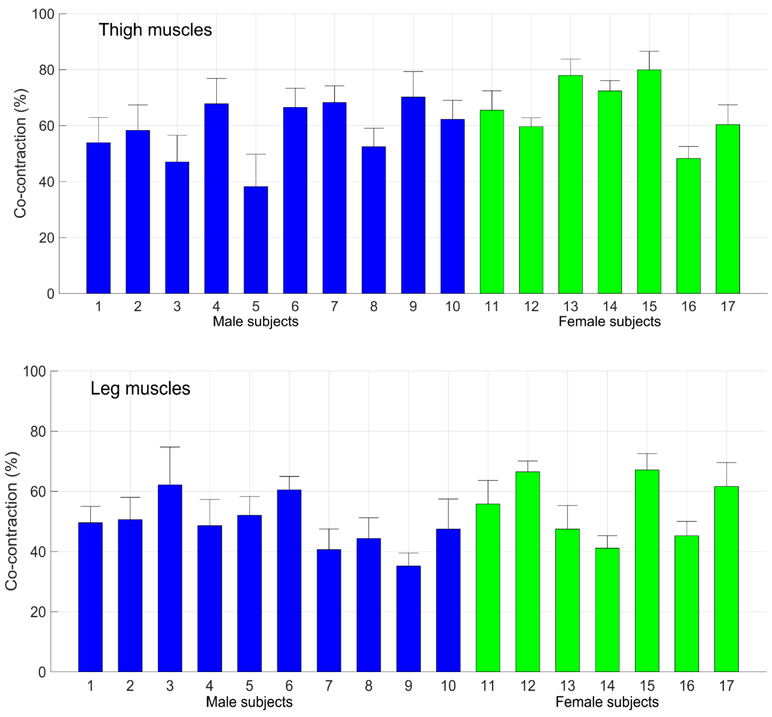


Figure 4. Co-contraction over the 10-minute gait trial for male and female subjects. Whiskers represent one standard deviation.

- **Large inter-subject co-contraction variations**
- **Larger co-contractions for thigh muscles than for leg muscles**
- **No significant co-contraction differences between male and female subjects**

DISCUSSION

- Large inter-subject co-contraction variations may explain why some people develop OA and some do not, even when exhibiting the same kinematics.
- Larger muscle co-contractions for the thigh than for the leg muscles may be correlated to the higher incidence of OA in the knee joint, which would confirm the role co-contraction plays in OA onset and progression.
- The lack of gender differences would indicate that the higher OA incidence in females [2] comes from kinematics or ground reaction force differences and not mainly from co-contraction.
- This study is the first critical step towards the development of a wearable skin that would mitigate muscle-co-contractions.

CONCLUSION & ON-GOING WORK

- **Large inter-individual muscle co-contractions exist even amongst young adults, which can explain why some people develop OA and others do not, even when exhibiting similar kinematic patterns.**
- **Gender differences in OA occurrence may not come from larger muscle co-contractions in females but rather from kinematic differences.**
- On-going work:
  - Recruit 20 older adults (50-60 years old) and investigate co-contractions.
  - Perform inverse dynamics calculations to compute joint contact forces for both age groups
  - Correlate muscle co-contractions with higher-than-normal joint contact forces.
  - Develop wearable sensors to estimate co-contractions in real time.
  - Develop wearable actuators that can relax muscles to prevent co-contractions.
  - Implement an effective control scheme.

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