Muscle activation patterns in healthy young adults during large postural sway exercises as measured through electromyography

Kübra Akbaş[1], Neethan Ratnakumar[1], Rachel Jones[1], Jean-François Daneault[2], Carlotta Mummolo[3], and Xianlian Zhou[1,*]

[1]Department of Biomedical Engineering, New Jersey Institute of Technology, Newark, NJ [2]Department of Rehabilitation and Movement Sciences, Rutgers University School of Health Professions, Newark, NJ
[3]Department of Mechanics, Mathematics and Management, Politecnico di Bari, Bari, Italy *alexzhou@njit.edu

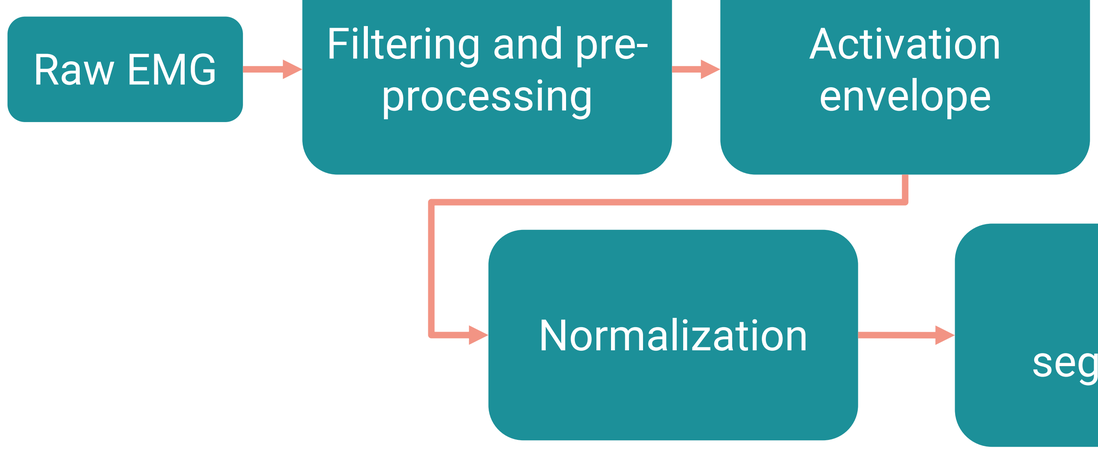
Introduction

- Reduced muscle performance can adversely affect balancing ability, such as in aging and Parkinson's Disease [1-4]
  → crucial to better understand muscle and balance
- Many studies focus on postural balance during quiet standing, but investigation of large postural sway is limited
- Aim: investigate muscle activation patterns during large postural sway, including exercises requiring assistance from an experimenter for recovery

Muscles:

- Gastrocnemius lateralis
- Gastrocnemius medialis
- Soleus
- Semitendinosus
- Biceps femoris
- Tibialis anterior
- Vastus medialis
- Vastus lateralis
- Rectus femoris
- Sartorius
- Rectus abdominis
- Erector spinae
- Multifidus
- Gluteus maximus
- Tensor fasciae latae
- Iliopsoas





Approach

- N=22 (11M,11F), age=25.15±5.11 years

Tasks:

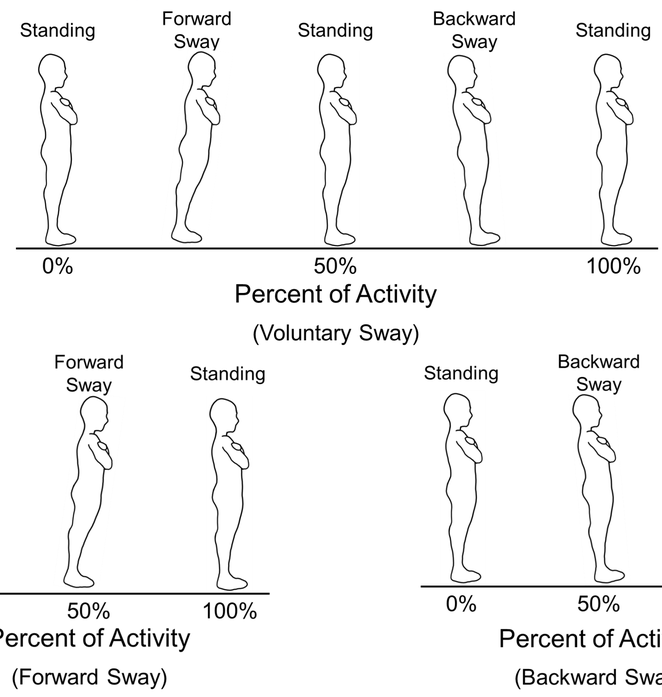
1) Maximum Voluntary Sway (Anteroposterior (AP) direction)
2) Supported Sway (AP direction)
3) Perturbed Sway (AP direction)

} Anterior & Posterior Isolated

Voluntary Sway | Anterior Sway | Posterior Sway



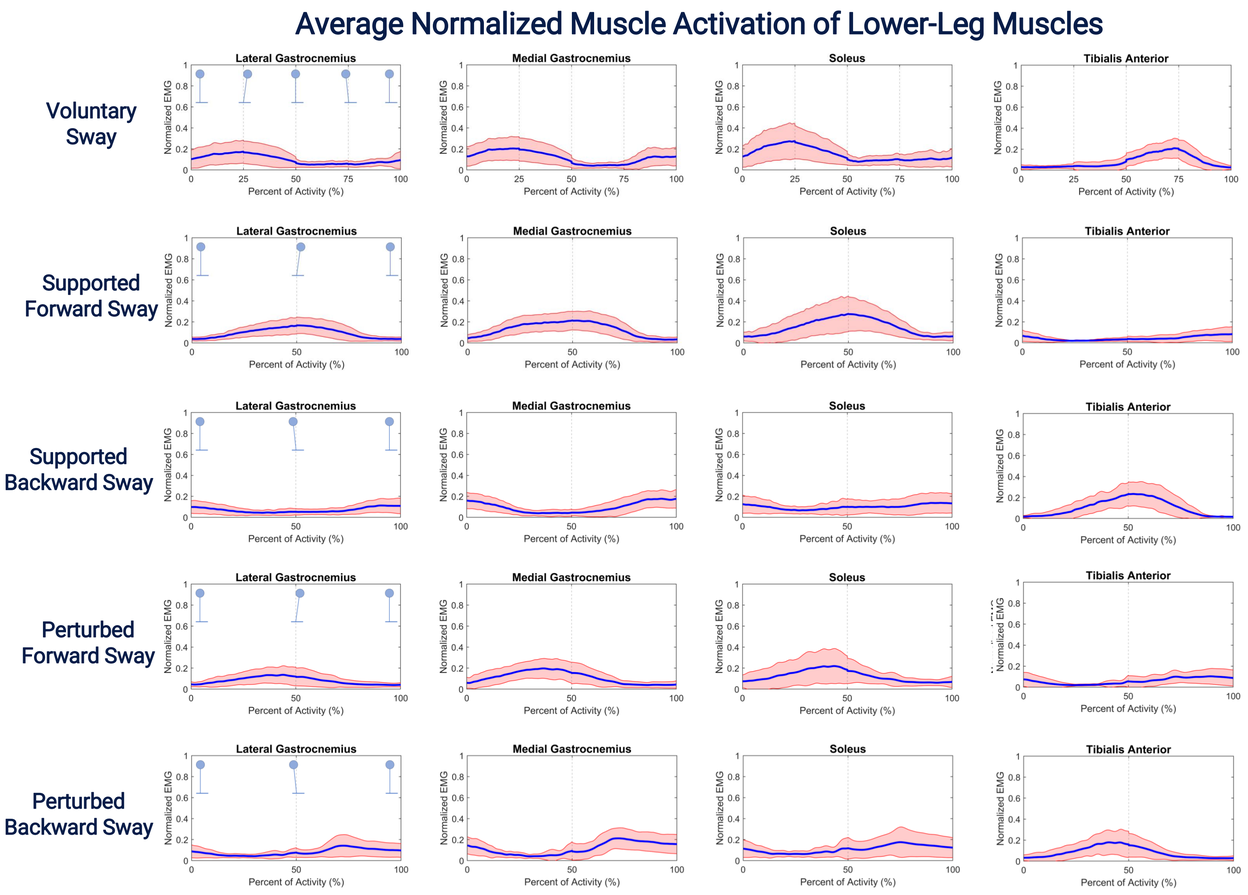
Activity Phases for Segmentation



Results

- Lower-leg muscles (e.g., gastrocnemius, soleus) had greater activation than hip, or knee muscles → ankle strategy
- Higher activation in counterbalance muscles (0.2 – 0.4)
  - Timing of peak activation shifts earlier during perturbed forward sway, but shifts after the perturbation in the backward direction
- Increased gastrocnemius activity after perturbation during backward sway → possible stabilization response to perturbation
  - Activation of calf muscles would indicate increased effort to maintain foot contain and prevent toe lifting
- Co-contraction occurs during perturbed backward sway, which could be due to fear from lack of visual feedback
- Back muscles more involved overall than other core muscles across all sway exercises → no noticeable upper body compensation during balance recovery

Average Normalized Muscle Activation of Lower-Leg Muscles



Conclusions & Future Work

- Overall, these experiments demonstrated the distinct muscle activation patterns during large postural sway and highlight the prominence of lower-leg muscle involvement.
- Ankle strategy was the main balance recovery strategy
- Gastrocnemius and soleus muscles were heavily involved in both anterior and posterior directions of sway
- Can contribute to future interventions aimed at strengthening and conditioning specific muscles
- Could explore additional EMG features, muscle synergies, and muscles for comprehensive understanding of balance control

References
[1] Carty et al. J. Gerontol. A. Biol. Sci. Med. Sci. 2012; 67(11), 1246-1252.
[2] David et al. Parkinsons Dis. 2012; 2012(1), 124527.
[3] De Groote et al. J. Biomech. 2017; 55:71-77.
[4] McKay et al. PLOS ONE 2021; 16(5), e0252119.