MECHANICAL ENGINEERING
TEXAS A&M UNIVERSITY

HUR (HUman Rehabilitation) Group http://hurgroup.net

SHARED AND TASK-SPECIFIC MUSCLE SYNERGIES DURING NORMAL WALKING AND SLIPPING

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INTRODUCTION

Motivation

- The CNS controls motor tasks using a low-dimensional modular organization of muscle activation (muscle synergies) [1] and some synergies might be shared across different behaviors [2].
- Falls-related injuries due to slip have been serious problems for workers and elderly adults [3].
- Knowledge about slip-related muscle synergies in healthy subjects may help understandings of the motor strategy to recover from slip and could be used as a gauge in diagnosis and rehabilitation.

Objectives

- To compare muscle synergies and their activation levels during normal walking and during slip initiation.

Hypotheses

- Some synergies are shared between normal walking and slip.
- Activation levels of the shared synergies are similar before the slip responses.

METHODS

Subjects

- 11 healthy young adults (6 male, 5 female, age=22-33)

Procedures

- Subjects were instructed to walk on a floor with four force plates embedded (Fig. 1).
- Right feet were ensured to hit first and third force plates.
- Four normal walking trials preceded an unexpected slip trial.
- To induce unexpected slip, subjects were informed that the surface would be non-slippery.
- Study was approved by University of Wisconsin-Milwaukee IRB.

Data Collection

- Surface EMGs were measured from 8 leg muscles (Fig. 2)
- Force plate data were collected to identify heel contact.

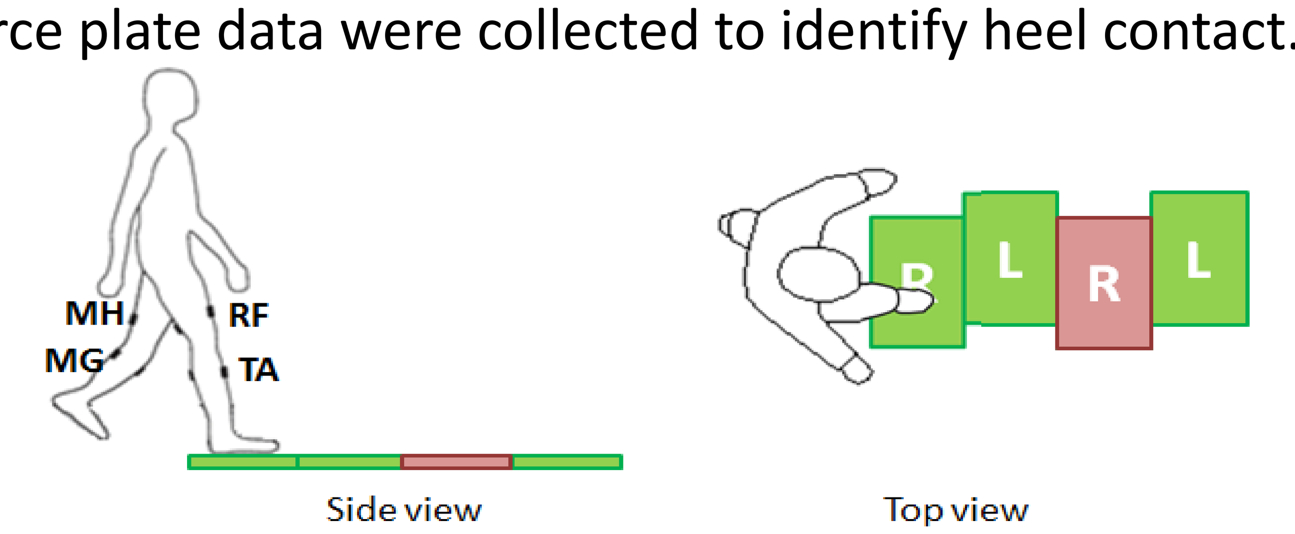

Fig. 1 Force plate setting and foot placements.

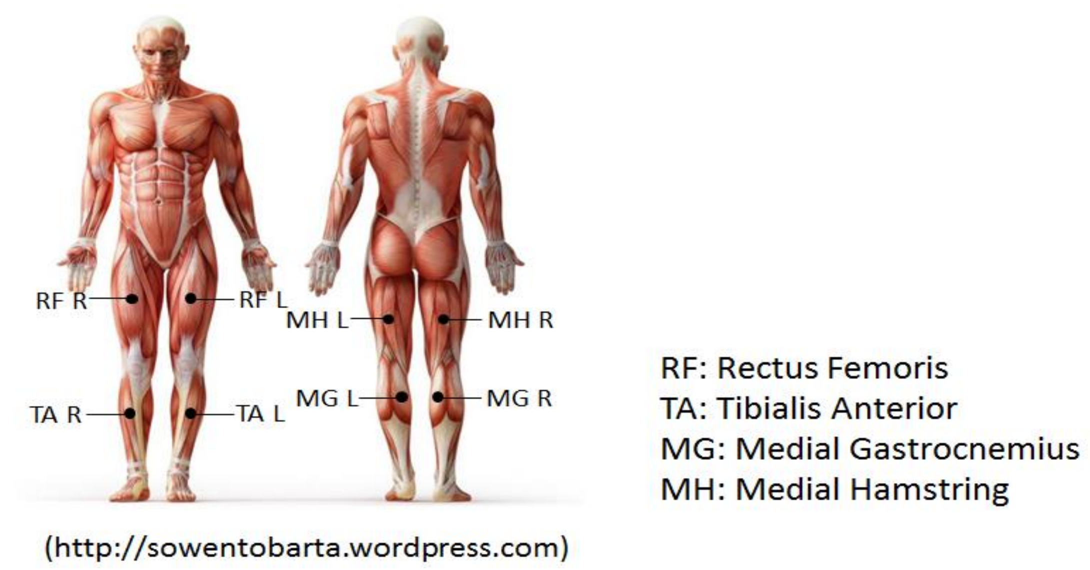

Fig. 2 Leg muscles on which EMG were measured.

Analysis

- Data for the 300 ms interval after heel contact on 3rd force plate were used for data analysis.
- A non-negative matrix factorization technique [4] was used on processed EMG to extract synergies and their coefficients for both conditions.
- Correlation coefficients (r) for all possible combinations of the four normal walking synergies and slip synergies (sixteen "r" values for each subject) were calculated.
- One sample t-test was used to check if r≥0.632 and r≥0.4 indicating high or marginal similarity between synergies, respectively.
- This procedure was repeated for activation coefficients.

RESULTS

- Four synergies were extracted for both walking and slipping(Fig. 3,4).
- There was one shared synergy (W1) between conditions (r=.82, p=.002) and one marginally shared synergy (W2) (r=62, p=.024), (Fig. 3).
- Before reaction time of brain (200 ms) [5], a significant correlation for activation levels of the first shared synergy between two tasks was observed (r=.84, p=.004). A marginally strong correlation was observed for the activation of second pair of shared synergies (r=.59, p=.026), (Fig. 4a).
- Two peaks for activation coefficient in response to slip after 200 ms were observed for the shared synergy (Fig. 4a) [5].
- Primary peak (first arrow, Fig. 4a) was to flex knee and dorsiflex ankle, achieved by first shared synergy.
- Secondary peak (second arrow, Fig. 4b) is knee extension and hip flexion, and is achieved by activation of the second shared synergy.
- Task specific synergies were responsible for the propulsive power of the support leg and dorsiflexion on the support leg for normal walking(W3,4 walk Fig.3 b), while for the slip, their function is to stabilize the leading foot and create a dorsiflexion on the support leg(W3,4 slip Fig. 3b).

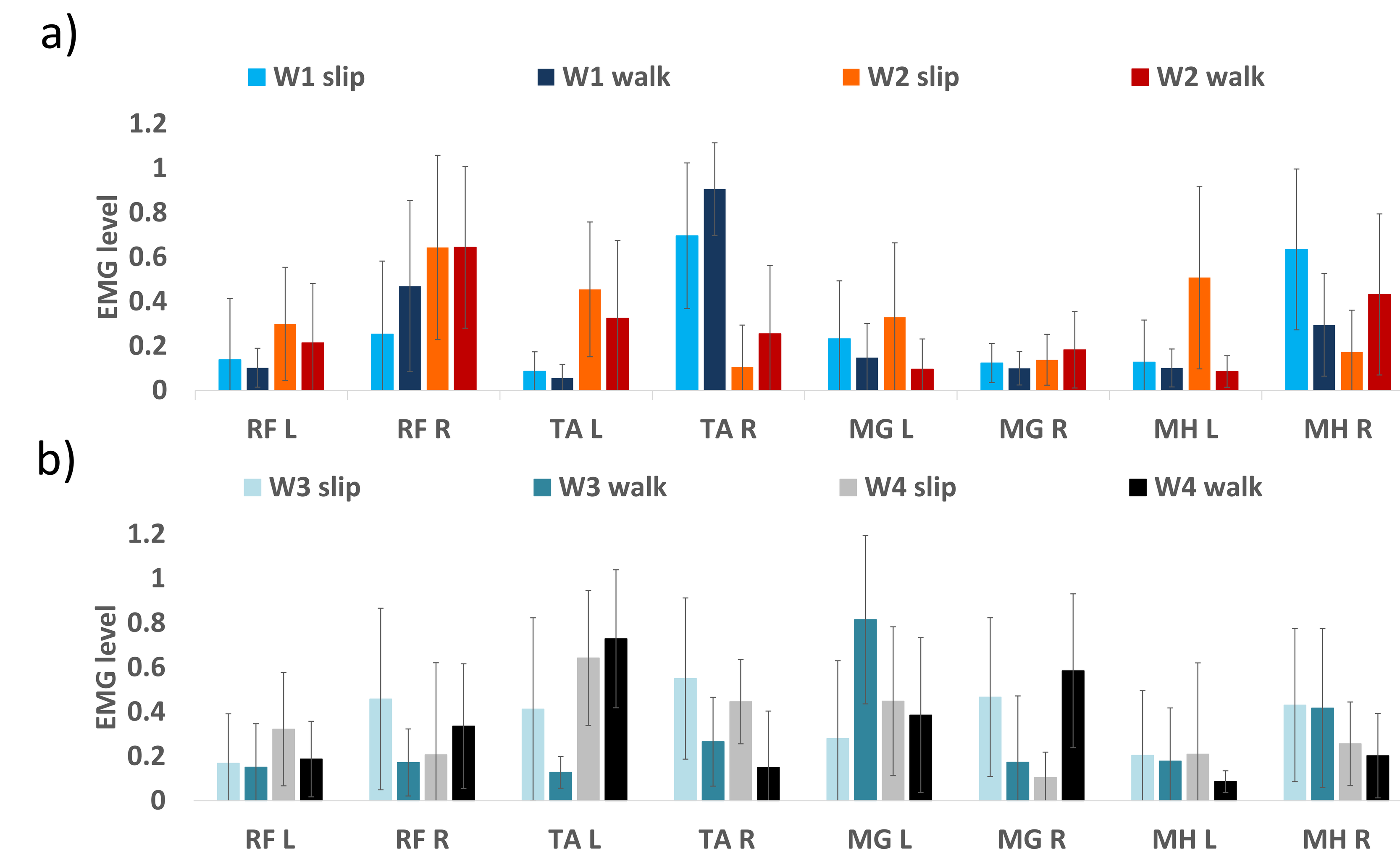

Fig. 3 Shared Synergies (a) and task-specific (non-shared) synergies (b) between conditions. Error bars are equal to one standard deviation. Different colors show synergies

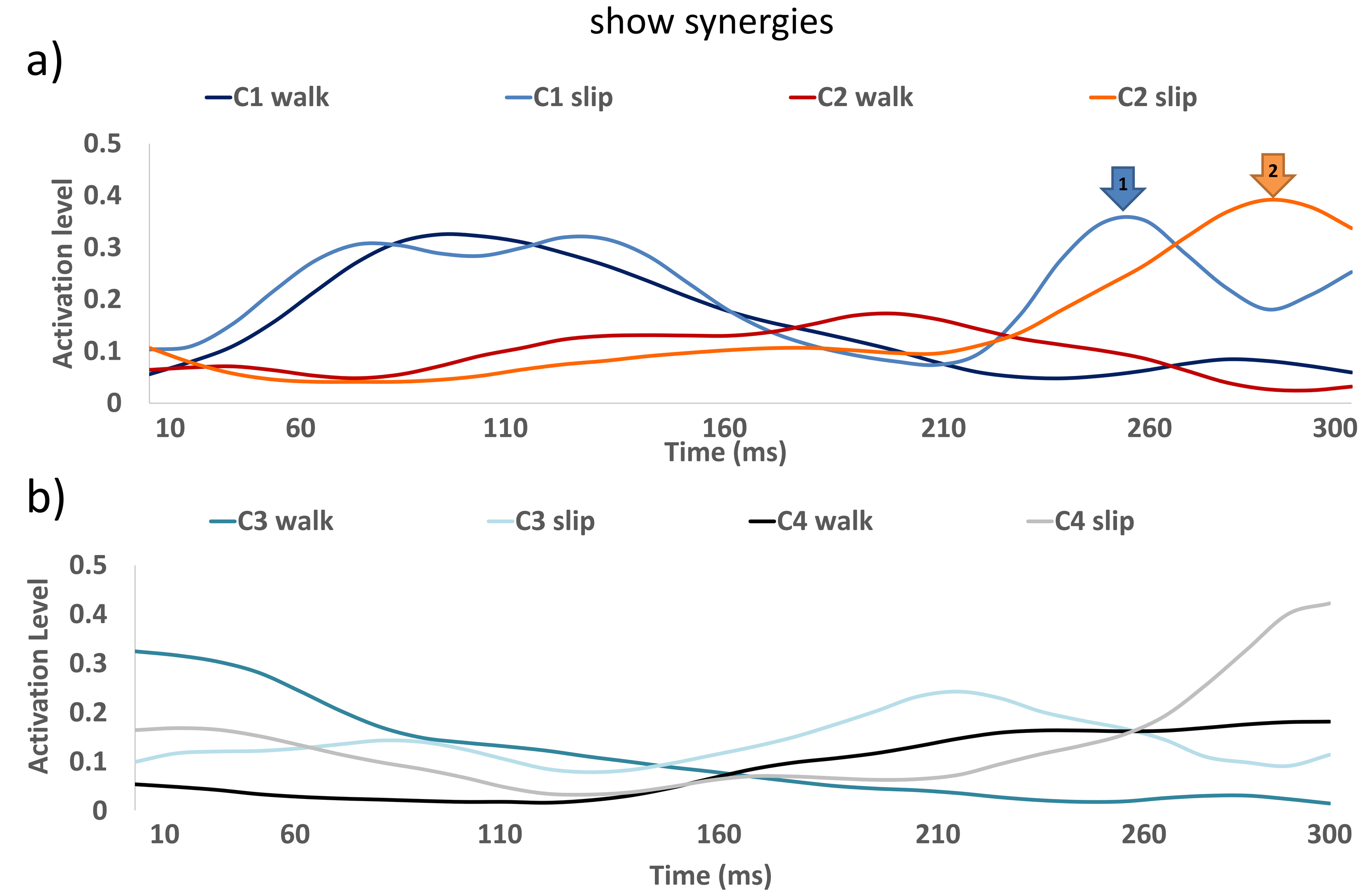

Fig. 4 Activation coefficients for shared (a) and task-specific (b) synergies. Each time step stands for 10 ms.

CONCLUSION

- Two shared and two task specific synergies were found between normal walking and slip condition.
- The activation levels of the shared synergies match among conditions before reaction of the brain.
- Future studies can further investigate subjects based on severity of the slip to identify the causes.

References

[1] d'Avella A, et al. *Nature neuroscience* **6**, 300-308, 2003.
[2] d'Avella A, et al. *PNAS* **102**, 3076-3081, 2005.
[3] Beschorner et al., IIE Occ Ergo and Hum Fact, 1(1), p31-37, 2013
[4] Ting LH, et al. J Neurophysiology 93, 609-613, 2005.
[5] Chambers AJ, et al. *Gait and Posture* **25**, 565-572, 2007