Predicting Grip Aperture using Forearm Muscle Activation Data

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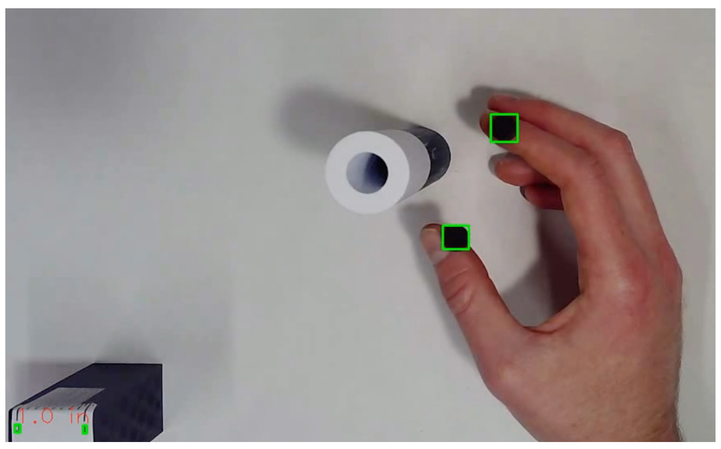
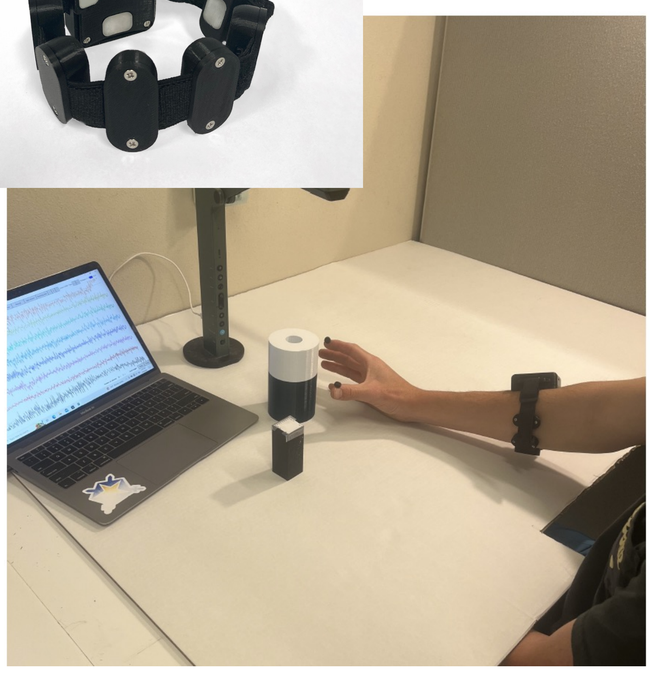
BACKGROUND

- Individuals with post-stroke hemiparesis often have difficulty performing tasks which require distal dexterity.[1-3]
- Activities of daily living (ADLs) are used to assess post-stroke recovery and functional independence.
- Reach-to-grasp (RTG) movements, critical for environmental interaction, are impaired post-stroke.
- Grip aperture, the distance between thumb and forefinger, is predictive of RTG success.
- Surface electromyography (EMG) offer a non-invasive method for remote monitoring of distal motor function.



OBJECTIVE

To develop a relationship between forearm electromyography (EMG) and grip aperture, with a long-term goal to develop tools for real-time monitoring and assessment of stroke patient ADL recovery.



METHODS

Participants

- 10 unimpaired individuals recruited from convenience sample (California Polytechnic State University, San Luis Obispo IRB approval #2022-082)

Procedure

- Participants simulated a grasp 10 times towards a cylinder without moving their hand.
- Five cylinders of increasing radii were used as visual indicators (D1: 0.5”, D2: 1”, D3: 1.5”, D4: 2”, D5: 2.5”).
- Grip aperture recorded using document camera and computer vision algorithm
- EMG recorded using MindRove armband

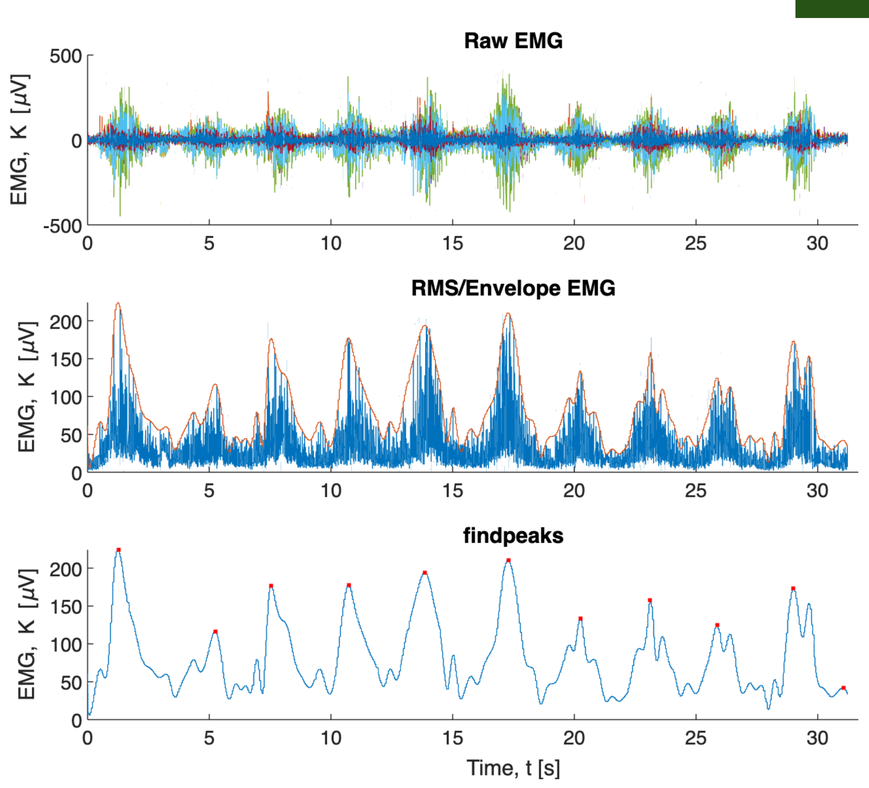
Data Pre-Processing

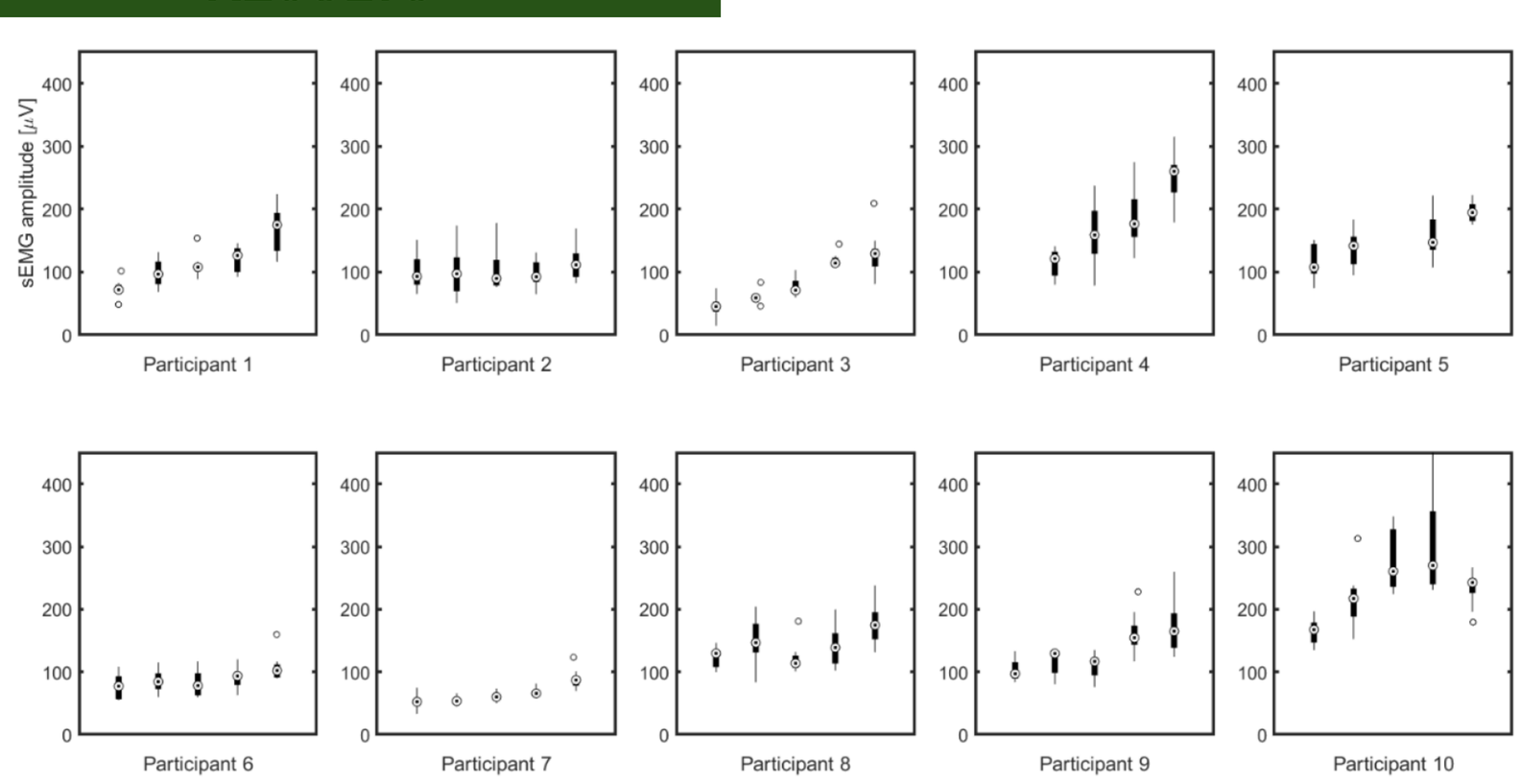
- Root mean square (RMS) of eight raw EMG signals calculated using MATLAB 2023

$$f_{RMS} = \sqrt{\frac{1}{n}(x_1^2 + x_2^2 + \ldots + x_n^2)}$$

- Signal processing toolbox commands *envelope* and *findpeaks* to de-noise signal and capture morphology

RESULTS





Obtaining Ground-Truth Finger Aperture

Aperture (ground truth) is positively correlated with peak EMG

Participant ID	Spearman's ρ	p-value
1	0.758	<0.001
2	0.208	0.152
3	0.883	<0.001
4	0.660	<0.001
5	0.700	<0.001
6	0.408	0.004
7	0.801	<0.001
8	0.304	0.033
9	0.746	<0.001
10	0.604	< 0.001

Determining Effects of Diameter

Peak EMG differs between cylinder diameters

Note: Bonferroni corrected p-values = 0.005

Diameter Relationship	Test Statistic, Z	p-value
D1 - D2	-3.563	<0.001
D1 - D3	-3.582	<0.001
D1 - D4	-5.722	<0.001
D1 - D5	-7.052	<0.001
D2 - D3	-2.361	0.018
D2 - D4	-5.111	<0.001
D2 - D5	-6.839	<0.001
D3 - D4	-3.884	<0.001
D3 - D5	-5.914	<0.001
D4 - D5	-4.326	<0.001

DISCUSSION & REFERENCES

Individual Performance

- Positive correlation between aperture and EMG for 9/10 subjects
- Consistent muscle activation for same-sized objects

Group Performance

- Statistically significant differences between cylinder diameter and peak EMG
- Significant differences across all diameters (excl D2-D3) suggesting non-linear EMG/diameter relationship

Limitations and Future Work

- Factors such as fatigue, acquisition time, and task repetition may influence EMG signal quality.[4]
- Future work aimed towards population of post-stroke individuals and developing models capable of extracting relevant features from continuous, longitudinal data

[1] R. O’Caoimh et al., “Risk prediction in the community: A systematic review of case-finding instruments that predict adverse healthcare outcomes in community-dwelling older adults,” Maturitas, vol. 82, no. 1, pp. 3–21, 2015.
[2] J. H. Medicine, “Effects of stroke.” https: //www.hopkinsmedicine.org/health/ conditions-and-diseases/stroke/ effects-of-stroke, 2024. Accessed: January 3, 2024.
[3] R. Chieffo et al., “Noninvasive neuromodulation in poststroke gait disorders: Rationale, feasibility, and state of the art,” Neurorehabilitation and Neural Repair, vol. 30, no. 1, pp. 71–82, 2016.
[4] M. Wang, C. Zhao, A. Barr, H. Fan, S. Yu, J. Kapellusch, and C. H. Adamson, “Hand posture and force estimation using surface electromyography and an artificial neural network,” Human Factors, vol. 65, no. 3, pp. 382–402, 2023. PMID: 34006135