Specific Manual Tasks Transform EMG into a Probe for Neural Dysfunction in Parkinson's Disease

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INTRODUCTION

Parkinson's disease is the second most common neurodegenerative disease. Without methods for screening and detecting the disease early, diagnosis often occurs only after the nervous system has sustained substantial and irreversible damage [1].

It may be possible to detect the subtle fingerprints of early disease within patterns of EMG
Specifically, many of the neural circuits involved in muscle coordination operate at distinct frequencies, and may function to 'bind' multiple muscles together into flexible, task-specific synergies [2]. The oscillatory action of these circuits causes muscles that have been 'bound' together to become synchronized with each other. This can be quantified in the frequency-domain using EMG coherence analysis [2,3].

Tasks based on muscle coordination could be used to 'probe' the integrity of coordination-related neural circuits
In this study, we measured EMG-EMG coherence between finger muscles while participants engaged in either a pinch-force modulation task, or a pinch-and-rotate task. One group consisted of healthy adults and a second group consisted of patients with mild-moderate severity Parkinson's disease.

During the rotation task, it was expected that a distinct ~40 Hz drive called the 'Piper Rhythm' would emerge due to the requirement of digit movement [4], but would be notably weak in the patient group, as this drive is reduced by dopamine depletion [5]. The pinch-force modulation task was expected elicit some 30-50 Hz coherence, but very little at ~20 Hz [6]. Patients were expected to show increased 20 Hz drive, as this may be related to the symptom of bradykinesia [7]. Of course, any tremor would tend to cause coherence at lower frequencies (<10 Hz).

Our overall hypothesis was that the patient group would show a reduced overall proportion of high (30-50 Hz) frequency coherence in both manual tasks. We also speculate that this reduction could serve as a diagnostic aid if the effects are sufficiently strong.

METHODS

EMG-EMG coherence was measured between the *abductor pollicis brevis* (APB) of the thumb and *first dorsal interosseous* (FDI) of the index finger of participants as they performed 3-minute manual task trials. The patient group consisted of 11 individuals (ages 42-69, 6 male), all on medication, and our preliminary control group consisted of 10 individuals (ages 24-36, 6 male).

In the first task, participants pinched a small dial as shown in Figure 1 A. They used visual feedback to generate a pinch force that was scaled slowly between 1 and 3 Newtons. The modulation rate was 0.1 Hz for patients and 0.25 Hz for our preliminary control group. In the second task, participants rotated the dial to the left and right ±22.5° at the same frequency. The color of the cursor indicated when forces fell outside of the 1-3 Newton range, to ensure that pinch forces remained similar to the force scaling task.

To evaluate coherence within each task, we calculated a 'gamma ratio' per participant, representing the proportion of total coherence within the 30-50 Hz frequency range. To evaluate differences across groups, we used an unequal variance t-test on ranked data. To evaluate effect size, we calculated Cohen's D. Finally, we evaluated the ability of the 'gamma ratio' to

discriminate patients from controls by determining the area under a Receiver Operating Characteristic curve (ROC_AUC).

RESULTS AND DISCUSSION

Figure 1 B and C display the average APB-FDI coherence across all participants in each group, and for each task. The coherence values have been transformed to standard Z-scores prior to averaging. The boxplots in Figure 1 D and E depict the results of calculating the proportion of total coherence in the 30-50 Hz band for each participant, in each group, and for each task. In both the rotation and scaling task, the proportion of coherence in the 30-50 Hz band was low in the patient group relative to the controls.

In fact, during scaling, this 'gamma ratio' differed significantly between groups ($p = 0.0012$), showed a large effect size (Cohen's $D = 1.08$), and good discriminability between patients and controls ($ROC\_AUC = 0.81$). For dial rotation, this gamma ratio statistically differed across groups ($p = 8.33e\text{-}5$), had a very large effect size (Cohen's $D = 1.58$), and showed excellent discrimination potential ($ROC\_AUC = 0.9$).

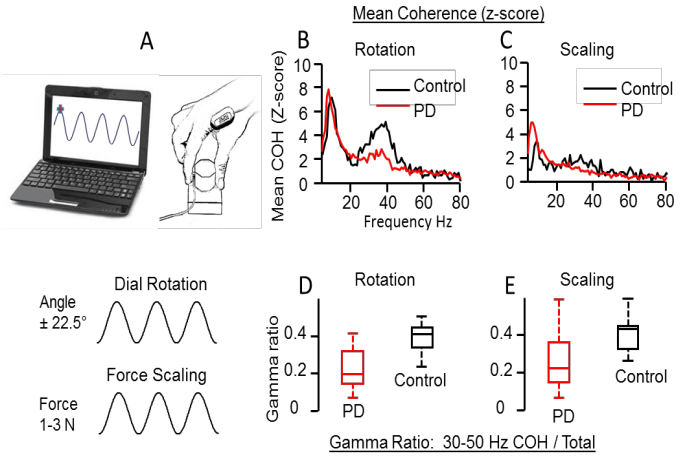

Figure 1: EMG-EMG coherence calculated during manual tasks (A) differs between healthy adults and those with Parkinson's disease (B-E).

It is relevant to note that neural drive to muscles has been studied in Parkinson's disease before, but the results have not shown diagnostic potential [5]. A major difference between our study and previous work is that we quantify muscle synchronization rather than neural drive to individual muscles. This takes advantage of the interpretation of high frequency EMG coherence as an index of neural 'binding' (i.e., an inherently coordination-related phenomenon). Our strategy is also unique in that physical tasks are designed specifically to evoke different frequencies of muscle-synchronizing drive, whose origins are thought to lie within relevant (in this case, disease-affected) neural circuits.

CONCLUSIONS

Our work demonstrates that simple measures of EMG activity in distinct neuromechanical contexts can be used to probe disrupted neural mechanisms in Parkinson's disease. This work shows a clear, if preliminary, example of how the specific study of neural drive as subordinate to basic mechanical task demands can be of great benefit in the clinical domain.

REFERENCES

1. Cheng et al. *Ann Neurol* **67**, 715–25, 2010
2. Nazarpour et al. *J Neurosci* **32**, 12349–12360, 2012
3. Boonstra TW. *Front Hum Neurosci* **7**, 855, 2013
4. Maurer et al. *J Electromyogr Kinesiol* **23**, 673–8, 2013
5. McAuley et al. *J Neurol Neurosurg Psychiatry* **70**, 471–475, 2001
6. Omlor et al., *NeuroImage* **34**, 1191–1198, 2007
7. Little et al. *Exp Neurol* **236**, 383–8, 2012

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