DISTINCTIVE CONTROL STRATEGY OF DYNAMIC FINGERTIP FORCE IN INDIVIDUALS WITH MILD TO MODERATE PARKINSON’S DISEASE AND ITS CLINICAL IMPLICATIONS

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INTRODUCTION

Individuals with Parkinson’s disease experience progressive impairment of sensorimotor control in fingers, which impacts on dexterous manipulation [1]. Basal ganglia are important neural substrates for grip force control [2]. Damage in basal ganglia might result in different behavioral strategies of grip force control. Using PD model, we may be able to study roles of basal ganglia in grip force control, investigating impairment of sensorimotor control of grip force in PD. However, measuring subtle changes of sensorimotor control in the hands for PD has been challenging because of the low sensitivity and specificity of commonly used clinical assessments, such as the Unified Parkinson’s Disease Rating Scales (UPDRS). The Strength-Dexterity (S-D) test has been validated to measure sensorimotor control of dynamic fingertip force at one’s maximal instability that he or she has to control [3]. The S-D test requires compressing a spring prone to buckling, and great involvement of basal ganglia was found during the spring task [4]. Therefore, the goal of study is 1) to investigate distinguishable control strategy of dynamic fingertip force in individuals with mild to moderate PD at one’s maximal instability and 2) how the findings will correlate with their motor impairment level for its clinical implications.

METHODS

A total of 22 individuals with mild to moderate PD (Hoehn and Yahr stages 1-3) (68.6 ± 7.5 yrs, 11M, 11F) and 41 age-matched individuals without disability (67.0 ± 9.2 yrs, 18M, 23F) participated in the study. The S-D test was used to measure dynamic sensorimotor control of fingertip force from the thumb and index finger. The spring is prone to buckling, and designed to be impossible to compress fully. Full compression requires < 3N, or about 6-7 % of the maximal voluntary contraction of the thumb and index pinch grip (~10lbs or 44.5N). The participants compressed the spring to its solid length as much as they could, sustained the compression for 5 seconds, and release the compression. Both affected and less-affected hands were measured for the PD group (PD_{aff} and PD_{less-aff}), and both dominant and non-dominant hands were measured for the control group (C_{dom} and C_{non-dom}). Customized miniature load cells (ELB4–10, Measurement Specialties, Hampton, VA, USA) at the end caps measured fingertip force in the compression direction. Force signals were sampled at 400Hz, down-sampled to 100Hz, and low pass filtered at 25Hz. The top three-sustained compression was selected for data analysis. Outcome measures were the maximal sustained compression force level (F) and force dynamics: the 1st derivative of F (F’) and its root mean square (RMS) variability from the mean sustained compression. The MDS-UPDRS motor examination was used to measure motor impairment for 14 participants from a subset of the PD group. Spearman rho coefficient was used to test association between the force outcome measures and motor impairment level.

RESULTS

Individuals with mild to moderate PD were able to compress the spring as well as the control group, revealing no significant difference in the group average maximal sustained compression level among four hands. However, how they controlled the instability at their maximal level was distinctive; force variability measured by F’ and RMS of the PD_{aff} was significantly greater than those of the
The greater force variability showed no correlation with the group compression force level in the PD group: $F'$ vs. $F$ ($p=0.07, p=0.74$) and RMS vs. $F$ ($p=0.03, p=0.90$) while force variability increased with the group compression force level in the control group: $F'$ vs. $F$ ($p=0.37, p=0.031$) and RMS vs. $F$ ($p=0.37, p=0.031$). Interestingly, the greater $F'$ and RMS in PD$_{aff}$ was negatively associated with the low UPDRS motor score (the lower the score, the less the motor impairment) and the lower UPDRS hand-only motor score while no correlation was found between $F$ and the UPDRS motor scores (Table 1).

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<thead>
<tr>
<th>UPDRS_motor</th>
<th>UPDRS_hand_only</th>
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<tr>
<td>$F$</td>
<td>$p=-0.042, p=0.887$</td>
</tr>
<tr>
<td>$F'$</td>
<td>$p=-0.192, p=0.512$</td>
</tr>
<tr>
<td>RMS</td>
<td>$p=-0.526, p=0.053$</td>
</tr>
<tr>
<td>RMS</td>
<td>$p=-0.479, p=0.083$</td>
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$p < 0.05$, **$p < 0.01$

The results of the correlation showed that the PD participants with less motor impairment exhibited higher $F'$ and higher RMS. As an example of differences in motor strategies, two PD participants with the same UPDRS hand-only motor score as 12 showed distinctive force control strategies as shown by the phase portraits of $F$, the 1st derivative of $F$ ($F'$), and the 2nd derivative of $F$ ($F''$) plotted during a sustained hold phase (Figure 1).

**CONCLUSIONS AND DISCUSSIONS**

Individuals with mild to moderate PD were capable of performing the challenging spring task at a similar level of instability as the control group. But they exhibited greater force variability in the PD$_{aff}$ as described by $F'$ and RMS. Damages in basal ganglia and its sensorimotor cortical closed loop in PD might result in greater force variability because the neural structures are involved in stimulus-response control including rapid automatic corrections [5]. The statistically significant correlation between higher force variability and less motor impairment as per the UPDRS motor scores suggests that force variability is compatible with healthy neurophysiological control of movement in an aging population [6]. Our methodology may be able to detect the progress of the disease as the gradual loss of this variability, which may be related to the loss of mobility in later stages of the disease seen as freezing, bradykinesia, and akinesia. Therefore, measuring changes of force variability with this unstable manipulation task might provide a higher resolution to quantify the progression of motor impairment than the UPDRS motor examination. This could be beneficial to determine a dosage of medication and parameters for deep brain stimulation; or measure motor fluctuations throughout the day.

**REFERENCES**


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