Finger Dexterity in Parkinson's Disease: A Novel Measure for Diagnosis and Staging

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Introduction

- It has been shown that the development of finger manipulation and dexterity occurs via formation of cortical-striatal pathways involving both the cerebellum and the basal ganglia.
- Hypothesis: Parkinson's Disease may lead to changes in this dexterity function.
- Dexterity quantification is not currently standardized in Parkinson's Disease and these tools may be useful for this purpose.
- There may be usefulness in early diagnosis and prognosis of the neurologic disease state, as well as in the evaluation and follow-up of these patients.
- This lab has developed three tools, which quantify the finger dexterity of the subject
  - Strength-Dexterity Test (S-D Test)
  - Static Grasp
  - Finger Tapping
- So far, we have assessed 7 patients with early to later Parkinson's Disease
  - Where applicable, UPDRS and medications were obtained
  - Patients were given time to practice each task
  - We defined diagnosis or 10 or more years prior as late PD and all others as early PD.

This study is approved under IRB Protocol:
HS-12-00463

Static Grasp

- Grasp an object with their thumb, index and middle fingers.
- The object is instrumented to measure kinematics and has load cells at the finger pads.

Testing Conditions:
1. Baseline, static hold.
2. Rotating the object in horizontal plain
3. Translation of the object along the plane of the ground in two directions.

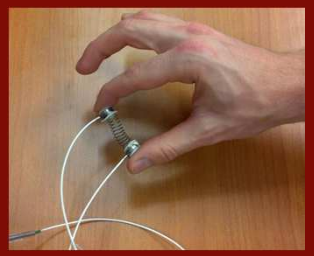
Analysis
- Each trial is analyzed using PCA analysis.
- With current data, no clear pattern has emerged. Given the low power of the study, this analysis is ongoing.
- Usefulness: Measuring the dynamic control of three fingers on a moving object may provide insight into the ability of the brain to coordinate forces in order to stabilize a dynamic system.

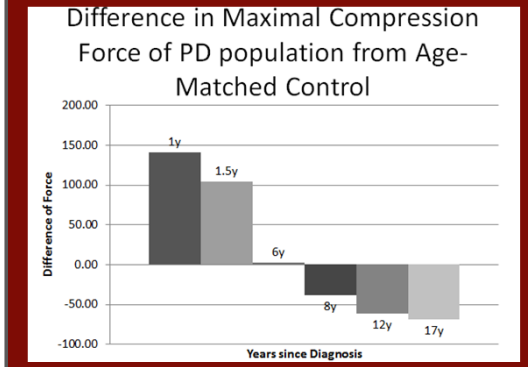
Methods and Results

Strength-Dexterity (SD) Test

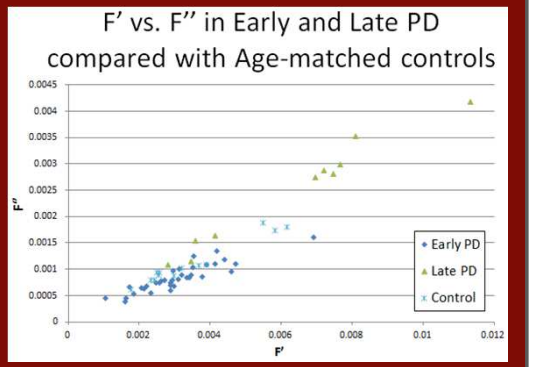
- Grasp slender compression springs with the tips of their thumb and index finger.
- When compressing the spring, it will become increasingly unstable until the subject reaches a maximal amount of compression that they can maintain – defined as "Maximal Compression Force"
- Load cells mounted on each end of the spring record the level of force for analysis and feedback to the subject.

Analysis
- Each hold phase is isolated and analyzed to calculate the Maximal compression force as well as the average velocity (F') and acceleration (F'') of each trial.
- Frequency of motion may be a useful measure given the specific characteristics of tremors in various conditions.
- Usefulness: Maximal Compression Force has been shown to be indicative of sensorimotor capabilities for stability of dexterous grasp.





The difference was found by subtracting the maximal compression force of an age-matched control from that of the PD population. There was a noticeable linear trend in this difference, where early PD patients had increased force and later PD patients had decreased force.



Absolute value of F' (velocity) and F'' (acceleration) were calculated from each hold phase longer than three seconds. Early PD patients showed similar velocity and acceleration to the control population, while late PD patients showed significantly larger velocities and accelerations with movement.

We would like to thank Kornelius Racz for the use of his code and all of his help in analysis of the static grasp data. We would like to thank Dr. Sue Duff for her consultation and support throughout the project. We would finally like to thank all the members of the Valero-Cuevas lab for their help in teaching two medical students about engineering and their answering our many questions.

Conclusions and Future

S-D Test:
- Differences shown within the PD population when stratifying between early and late disease, particularly in velocity of motion during a stable compression.
- Late patients display a much larger velocity, possibly due to the marked tremor which affects these patients.
- Difference in the maximal compression force between the control and sample populations.
  - Hypothesis: this increase in maximal compression force in early PD patients is due to the rigidity that is seen early in PD, and associated with postural rigidity before the characteristic tremor is demonstrated.
  - Hypothesis: trend of decreasing compression force as the disease progresses might be due to the change in balance of symptoms: the tremor becomes more pronounced and thus the maximal compression force – a stable force – is decreased.
- Conclusion: SD test should be further studied as a useful tool for measurement of dexterity in PD.

- Future:
  - Recruitment of more patients to test
  - Optimize analysis of Static Grasp and Tapping tests
  - Conversion of useful tools into a mobile suite that could be administered by healthcare providers in any setting

Tapping

- Index finger taps surfaces with different levels of friction.
- The surface is mounted on a load cell that measures the three-dimensional forces produced by the fingertip.

Testing conditions
1. Relaxed state to maximal force hold.
2. Low force state to maximal force hold.
3. Tapping to maximal force hold.

Analysis
- Each trial is analyzed by comparing the angle of the force vector with respect to time.
- The analysis function is still being optimized at this time.
- Usefulness: The ability to produce well directed force has been shown to be an indicator of the nervous system's ability to produce the controlled finger motions and forces necessary for everyday dexterous tasks.