Research of Parkinson's disease affected upper extremity biomechanics

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Abstract. In this paper we investigate the biomechanics of upper extremity of Parkinson's disease (PD) subjects in order to create an alternative quantitative diagnostic tool that could be used in clinical setting during diagnosing and monitoring PD. Wireless inertial sensors were used to measure angular velocity and acceleration during multi-joint arm motion tasks from ten PD and ten control (CO) subjects. Mean rest tremor was statistically significantly different between the PD and CO groups. Estimated maximum joint torque values of shoulder and elbow joints were statistically significantly different between the CO and PD groups.

Keywords: Parkinson's disease, biomechanics, upper extremity, wireless inertial sensor, OpenSim.

Introduction

Parkinson's disease is neurodegenerative movement disorder characterized by bradykinesia, rigidity, resting tremor and postural instability [1]. Despite the fact, that PD is a common disorder, accurate diagnosis remains challenging especially in early stages of the disease. Typically, PD is diagnosed clinically using Unified Parkinson's Disease Rating Scale (UPDRS). There are other rating scales, although have not been fully evaluated for validity and reliability [2, 3]. In this study we collected upper extremity kinematic data from PD and healthy control (CO) subjects and investigated features and metrics that may aid in quantitative diagnosis. Our long term goal of this research is to discover biomechanical markers of PD in order to facilitate clinical diagnosis and monitoring of the disease progression.

Methods and materials

Research was carried out on volunteers who were divided into two groups – 10 CO subjects (6 men, 4 women, aged: 65 ± 8 (mean ± SD)) and 10 PD subjects (5 men, 5 women, aged: 71 ± 7 (mean ± SD)). Three wireless sensors, each able to measure linear acceleration, angular velocity and magnetic heading in three dimensions were attached to each patient's hand, forearm and arm (Fig. 1). For the arm and forearm the x–y plane of the sensor's coordinate system was aligned as best as possible to the sagittal plane of the subject. Sensors recorded data at 51.2 Hz. The subjects performed three tremor tasks and eight sagittal plane upper extremity movement tasks. Three tasks each requiring increasing amounts of shoulder joint flexion were performed with and without a dual contralateral open-close hand task.

The tremor tasks consisted of a rest (hand on lap), action (repeated nose touching) and postural (arm outstretched) task. MATLAB software was used to calculate the root mean squared (RMS), peak-to-peak (Pk-Pk), power in 3–8 Hz frequency band (PR) and approximate entropy (ApEn) of the hand's acceleration signal. A one-way ANOVA with a significance level of $\alpha = 0.05$ was used to test the null hypothesis that the RMS, peak-to-peak, 3 to 8 Hz power and approximate entropy in the rest, postural and action tremor signals were the same between the PD and CO groups. The following metrics were calculated from the sagittal plane multi-joint reaching tasks: shoulder and elbow joint peak velocity (PV °/s), reaction time (RT s), dwell time at target (DT s) and maximal joint torque for shoulder and elbow joints (T_s and T_e Nm). The last parameters (T_s and T_e) were estimated from the inverse dynamics analysis of the recorded motion of the upper extremity using a musculoskeletal model of an arm and OpenSim software.

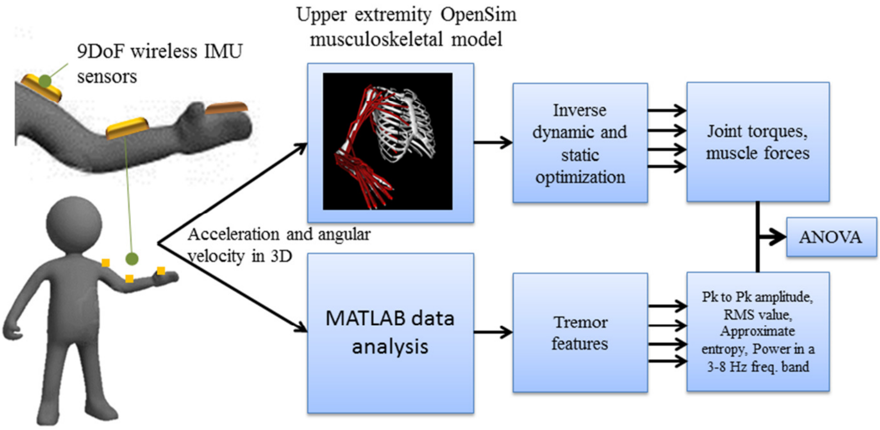

Fig. 1. Upper extremity motor biomechanics evaluation setup

Two-way repeated measures ANOVAs with a significance level of α = 0.05 were used to test three null hypotheses: that the means of the metrics (peak velocity, reaction time, dwell time, peak acceleration) grouped by disease type were the same; that the means of the metrics grouped by the dual/non-dual tasks were the same; and that there is no interaction between the disease types and dual/non-dual factors. A one-way ANOVA with a significance level of α = 0.05 was used to test the null hypothesis that the maximal joint torques values were the same between the PD and CO groups.

Conclusions

In general we found the feature that best distinguished PD patients from CO subjects was their rest tremor, as measured by either an RMS or Pk-Pk metric. For the rest tremor the mean (SD) of the RMS, Pk-Pk, and ApEn were 0.912 m/s^2 (0.916 m/s^2), 3.128 m/s^2 (3.323 m/s^2), and 0.802 (0.332) respectively for the PD group. These three means were found to be statistically significantly different than the mean RMS, Pk-Pk, and ApEn, for the CO group which were 0.061 m/s^2 (0.008 m/s^2), 0.159 m/s^2 (0.020 m/s^2), and 1.285 (0.040), respectively. For the upper extremity multi-joint movement tasks we found no statistically significant differences between the PD and CO groups regardless of the metric analyzed (PV, RT and DT). It was estimated, that the max shoulder torque (SD) T_s = 43.7 (3.9) Nm and elbow T_e = 16.6 (1.5) Nm for CO group were found to be statistically significantly different ($p = 0.03$ for shoulder joint and $p = 0.02$ for elbow joint respectively) for PD group (T_s = 20.8 (2.2) Nm and T_e = 7.6 (0.7) Nm).

References

[1] **Suchowersky O., Reich S., Perlmutter J., Zesiewicz T., Gronseth G., Weiner W.J.** Practice Parameter: Diagnosis and prognosis of new onset Parkinson disease (an evidence-based review): Report of the Quality Standards Subcommittee of the American Academy of Neurology, Neurology, 2006, (66), p. 968–975.

[2] **Ramaker C., Marinus J., Stiggelbout A. M., Johannes Van Hilten B.** Systematic evaluation of rating scales for impairment and disability in Parkinson's disease, Movement Disorders, 2002, (17), p. 867–876.

[3] **Ebersbach G., Baas H., Csoti I., Müngersdorf M., Deuschl G.**, Scales in Parkinson's disease, Journal of Neurology, 2006, (253), Suppl. 4: IV32–35.