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Tests of manual dexterity and speed in Parkinson's disease: Not all measure the same

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A B S T R A C T

Introduction: Timed performance tests were introduced to overcome the disadvantages of subjective evaluation of bradykinesia in Parkinson's disease (PD). We aimed to verify their discriminative properties and compare them with the motion capture analysis of finger tapping.
Methods: We included 22 PD patients (10 M, 12 F), mean age 64 (range 48–82) yrs, Hoehn & Yahr stage 2 (1–2.5) and 22 (10 M, 12 F) normal controls, mean age 66 (41–82) yrs. The key tapping subtest of the Halstead-Reitan battery, the Purdue Pegboard test, and the Bradykinesia-Akinesia Incoordination (BRAIN) test were performed according to the test manuals. The finger tapping subtest of the UPDRS-III, item 23 was recorded using a contactless 3D motion capture system Optitrack-V120. Average frequency (AvgFrq), maximum opening velocity (MaxOpV) and amplitude decrement (AmpDec) were computed and simultaneous video recordings of finger tapping were rated by two experts.
Results: The AmpDec and MaxOpV motion capture measures best differentiated between PD patients and controls (AUC = 0.87 and 0.81). Of the instrumental tests, only the Purdue Pegboard attained significance in differentiating PD patients from controls (AUC = 0.80). In PD patients, MaxOpV correlated with the finger tapping ratings and BRAIN test, and AvgFrq correlated with the BRAIN and Halstead-Reitan test scores. Moreover, correlations were found between the Purdue Pegboard and finger tapping ratings.
Conclusions: Contactless 3D motion capture of finger tapping allowed an independent analysis of individual components of bradykinesia, demonstrating the amplitude decrement and maximum opening velocity as the most powerful discriminators between PD patients and controls.

1. Introduction

Bradykinesia is considered as the key feature of Parkinson's disease (PD) and is used as a general term encompassing not only motor slowness, but also poverty of spontaneous movements (akinesia) and reduced amplitude of movements (hypokinesia) [1,2]. Because of the complexity of bradykinesia, clinical evaluation is not easy and low inter-rater reliability has been demonstrated for simple tests such as finger tapping [3]. Various attempts to refine scoring by separating the evaluation of individual components were not successful in achieving broader use of the newly proposed scales [4].

Alternatively, various timed performance tests were proposed to evaluate bradykinesia, with the aim to overcome the disadvantages of subjective evaluation and provide continuous measures instead of ordinal values [2,5]. Thus, instrumental tests have been in use for more than 50 years, to measure manual dexterity and movement speed in Parkinson's disease (PD). In 1960, Burns and De Jong tested various mechanical devices to evaluate the motor effects of pallidotomy in PD [6]. Notably, timed finger tapping rated with a mechanical counter and the number of pins placed in a pegboard were suggested as numerical measures of the severity of PD signs, which

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could be used to monitor the effects of therapy and variations in time [6]. More recently, various computerized tests were introduced to quantify upper limb motor function (e.g. alternating finger tapping at a computer keyboard) [7]. To date, while multiple electronic device-based upper limb function assessments are in use [8], instrumental finger tapping and pegboard tests still abundantly serve PD research, including recent clinical studies [9–11]. However, only few studies assessed the properties of the instrumental tests in more detail [12–16]. It can be assumed that various technical solutions that modify the weight of body parts or skin perception (e.g. accelerometers, sensory gloves) can affect the parameters of movement and distort the measurement results. In contrast, a contactless measurement with a 3D camera system, allows capturing the movement without any restrictions or conditions change [17].

Thus, we aimed to verify the utility of classical instrumental tests of upper limb motor function to differentiate between PD patients and normal controls. We also analyzed the measures of motor and sensory timing and the parameters of finger tapping using a contactless motion capture system [17].

2. Methods

We included twenty two patients (10 M, 12 F), mean age 64 (range 48–82) yrs, with mild to moderate PD, mean Hoehn & Yahr stage 2 (1–2.5), age at PD onset 55 (35–71) yrs, disease duration 9.3 (1–24) yrs, levodopa equivalent daily dose 884 (280–2080) mg, UPDRS-III score in the ON state 16 (6–34). Patients with tremor dominant form of PD or with marked motor fluctuations or dyskinesias were not included. Twenty two (10 M, 12 F) volunteers, of mean age 66 (41–82) yrs, without history of neuropsychiatric disorders and without any impairment of upper limb function served as normal controls. All subjects gave their informed consent to participate in the study. The study was approved by the Ethics Committee of the General University Hospital in Prague, Czech Republic, and therefore performed in accordance with the ethical standards established in the 1964 Declaration of Helsinki.

Each subject was examined in a single session of about one hour duration. PD patients were in their best on-medication state, which was verified with testing the motor part of the Unified Parkinson's Disease Rating Scale (UPDRS-III) at both the beginning and the end of the session.

Handedness was assessed using the revised form of Edinburgh handedness inventory [18].

The key tapping subtest of the Halstead-Reitan neuropsychological battery was administered according to the test manual (The Neuropsychology Center, P.C.). Participants were instructed to tap the lever of the counting device with their index finger as quickly as possible for ten seconds, keeping the wrist and arm stationary. This was repeated five to ten times, until the examiner had collected counts for five consecutive trials that were within five taps of each other. The test score was calculated as mean count of the five trials. Before starting the test, individuals were given a practice session. They were also given brief rests between each 10-s trial and one to two-minute rests after every third trial. The subject's dominant hand was examined first and the entire procedure was then repeated with the non-dominant hand.

In the Purdue Pegboard Test (Lafayette Instrument Company), the subject was instructed to pick up pins one at a time using only his dominant hand and to insert them into holes on the board as fast as possible for 30 s. The mean number of pins placed in the board for two consecutive trials served as the test score for the dominant hand. The same was done for the non-dominant hand.

Several tests were performed using a computer keyboard as the test device. For the Bradykinesia-Akinesia Incoordination (BRAIN) test, participants were seated comfortably in front of the keyboard and instructed to alternatively strike the target two keys 15 cm apart with their index finger, as fast and as accurately as possible for a period of 60 s. The kinesia score was defined as the number of keystrokes in 60 s [7]. The test was performed with the dominant hand first, followed by the non-dominant hand.

Further on, to measure simple reaction time (SRT) to visual stimuli, subjects were asked to watch the screen and to press a key with their index finger, as fast as possible after a black fixating cross in the middle is replaced by a blue square for a period of 100 ms. Reaction time was calculated as mean of 10 trials. Spontaneous motor tempo (SMT) was determined by asking participants to freely tap a keyboard key with their index finger at a comfortable rate [19]. Finally, subjects were asked to adjust rhythmic auditory clicks to their preferred sensory tempo using up and down arrow keys [20].

The finger tapping subtest of the UPDRS III, item 23 was recorded using a contactless three-dimensional motion capture system Optitrack-V120 (Suppl.1). The system measured the mutual distance of light passive reflexive markers placed on the distal phalanx of the thumb and forefinger [17]. Subjects were instructed to tap the index finger against the thumb as quickly as possible and with the largest amplitude possible. The test was performed by each hand twice for 15 s. Computational analysis of the recordings was performed as described in Suppl 1 [17]. Average frequency (AvgFrq), maximum opening velocity (MaxOpV) and amplitude decrement (AmpDec) were chosen as movement descriptors (Suppl 1). Averages of the test's movement descriptors obtained in two recordings were used for further calculations. Simultaneous video recordings were obtained by a common HD camera mounted on the same rack. The videos were independently rated by two movement disorders specialists (KZ and ER), according to the UPDRS-III item 23 criteria. The recordings from both the PD and the control group were presented in a random order, showing only the subject's hand and shading the rest of the picture window. Satisfactory agreement between the two raters was proven by computation of Cohen's kappa coefficient ($\kappa = 0.59$, moderate agreement). Therefore averages of both expert scores of finger tapping rated from video were used in further calculations.

2.1. Statistics

Statistical comparisons between PD patients and controls and between test results and clinical data were based on more affected hand performance in PD patients and dominant hand performance in controls. There were no statistically significant differences between non-dominant and dominant controls' hand in observed parameters (Supplemental Table 1). Wilcoxon rank sum test was applied for testing the hypothesis of PD and controls median equality. A Bonferroni correction for multiple comparisons was applied subsequently, after which p-values of 0.005 or lower were considered as statistically significant. Receiver operating characteristic (ROC), its area under curve (AUC) and Hanley-McNeil's 95% AUC confidence intervals were computed. Sensitivity and specificity was determined as the optimal operating point of the ROC curve. As secondary analysis, to explore relations between timed performance tests and parameters of finger tapping, Spearman's correlation test was performed in the data obtained from more affected hand in PD patients. P-values of 0.05 or lower were considered as statistically significant in these secondary correlation analyses. Statistical analyses and data processing were performed using MATLAB.

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