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# The effect of the Fascial Distortion Model on Micrographia in Parkinsonism - a single system study

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## 2. Acknowledgements

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## 3. Abstract/Key words


### Introduction

Patients with idiopathic Parkinson's disease typically suffer from a wide range of motor and non-motor problems. Besides the cardinal symptoms of akinesia, tremor and rigidity, micrographia, another common symptom in Parkinson's disease, is characterized by small handwriting with further progressive reduction in size. There is no proven theory that could explain the pathophysiology of micrographia exactly. The therapies described so far are time-consuming and involve a high risk of relapse. Until now, there exists no specific manual treatment for improving micrographia in neurorehabilitation.

### Methodology

The method according to the fascial distortion model addresses local changes in the area of the forearm fascia. It is suited to reduce functional impairments associated with this symptom complex by applying targeted manual techniques.

### Main Outcome Measures

One patient (male) participated in the study. A writing sample was used for the quantification of the writing skills. Subsequently four treatments of the forearm fascia were performed (once a week in four weeks). A follow-up measurement of four weeks was taken.

**Results**

Evident improvements of writing speed, letter height and surface area were achieved. Surprisingly, rigidity and diadochokinesia were improved as well. The long-term measurement showed no deterioration of the effects.

**Discussion**

The fascial distortion model is a potential effective and low-priced method for influencing writing skills in patients with idiopathic Parkinson's Disease. In order to change also neurological parameters, the treatment acts as a bottom-up therapy and changes even neurological pathways and the perspective of understanding the disease.

**Conclusion**

FDM probably fills in a current gap in neurorehabilitation. Therefore, more research on FDM is necessary in order to make reliable conclusions on its efficiency in long-term rehabilitation. Larger randomized studies are needed to confirm these results.

**Keywords:** Parkinson's Disease, Fascial Distortion Model, Micrographia and Handwriting

## 4. Introduction

### 4.1 Epidemiology of the idiopathic Parkinson disease (iPD) and the occurrence of micrographia

Idiopathic Parkinson's disease (iPD) is the second most common neurodegenerative disease after Alzheimer's disease, its prevalence reaching 1% of individuals over 60 years old [1]. Worldwide, there are approximately 4.1 million patients. According to studies, the number will increase to around 8.7 million by the year 2030$^{th}$. More than 15'000 patients live in Switzerland [2].

Patients with idiopathic Parkinson's disease (iPD) typically suffer from a wide range of motor and non-motor problems [3]. Besides the cardinal symptoms of bradykinesia (slowness of movement), tremor and rigidity (muscular stiffness throughout the range of passive movement in a limb segment) and postural and gait impairment, micrographia, another common symptom in Parkinson's disease, is characterized by small handwriting with further progressive reduction in size [4]; [5]. Micrographia has a high association with accurate diagnosis of Parkinson's disease [6]; [7]. Moreover, this problem can occur early in the disease and is one of the first symptoms ([4]; [8]; [9]); thus, it may be useful for early diagnosis of Parkinson's disease ([5]; [10]). Parkinsonian handwriting is often characterized by lack of fluency, slowness, and less frequently by micrographia.

The neurophysiological mechanisms underlying micrographia in iPD remain unknown [11]. It has been suggested that micrographia is a component of bradykinesia, as these two symptoms are correlated [5]. Inappropriate scaling of the dynamic muscle force to the movement parameters, which has been proposed to contribute to bradykinesia [12], may be a reason for micrographia ([13]; [5]). However, the relationship between micrographia and bradykinesia remains controversial [4]. It is well known

that micrographia can present at an early stage of Parkinson's disease, even without significant bradykinesia [11].

A cross-sectional study with 68 iPD-patients identified micrographia in 63.2% of the cohort [5]. In a study of Ponsen et al. participants wrote a complete sentence and the authors showed that letter height decreased in iPD-patients as writing progressed [9].

Handwriting is an important skill in all daily life. Any clinical condition that affects this will have a significant impact on the patient. When patients present with an initial complaint of micrographia, studies have shown that this symptom significantly increases the likelihood of having PD (with positive likelihood ratios of 3-6) [14].

Micrographia usually manifests in two forms: 'consistent' and 'progressive'. Consistent micrographia is a total reduction in writing size compared with writing before the development of the disease, whereas progressive micrographia is a gradual reduction in size during writing [15]. Most patients with micrographia exhibit both consistent and progressive micrographia [11].

### 4.2 Therapy approaches

Micrographia is likely a manifestation of hypokinesia (smallness of movement), and can be alleviated by levodopa [4] or high-frequency stimulation of the subthalamic nucleus [16]. Levodopa also improves kinematics of handwriting, such as velocity, acceleration, and stroke duration [17]; [18]. It has been commonly observed that external visual, auditory or verbal cues or attention can effectively increase the amplitude of handwriting in iPD-patients with consistent micrographia ([19]; [20]; [21]; [22]). Until now, there exists no specific manual treatment for improving micrographia in iPD-patients.

### 4.3 The Fascial Distortion Model (FDM)

The fascial distortion model (FDM) is an anatomical perspective in which the underlying etiology of virtually every musculoskeletal injury (and many neurological and medical conditions as well) is considered to be comprised of one or more of six specific pathological alterations to of the body's connecting tissues (fascial bands, ligaments, tendons, retinacula, etc.). In the manipulative practice of the FDM (known as Typaldos manual therapy, or TMT), each injury is envisioned through the model and the subjective complaints, body language, mechanism of injury, and objective findings are woven together to create a meaningful diagnosis that has practical applications. These diagnoses describe the conception of how the fasciae are twisted in a specific body segment where they cause specific problems [23].

### 4.4 Aim of the study

The aim of the case study was to

i. evaluate the effect of FDM on micrographia in idiopathic Parkinson's Disease
ii. analyze long-time effects of FDM on micrographia in patients with idiopathic Parkinson's disease and
iii. determine if other motor dysfunctions (motor status, range of motion, bradykinesia, rigidity, diadochokinesia) could be influenced by FDM.

## 5. Materials and Methods

### 5.1 Patient

One Patient with a diagnosed idiopathic Parkinson's Disease (Hoehn & Yahr scale I-III) was researched for the study. Handwriting problems, reflected by a score of 1 or more on the handwriting item (2.7) of the Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS) part II; General clinical characteristics of the patient such as gender, age, height, weight, disease duration and most affected side and levodopa equivalent dose (LED, mg/24h) were assessed. Specific in- and exclusion criteria are listed below.

Inclusion criteria consisted of:

i. a diagnosis of PD according to the United Kingdom PD Society Brain Bank criteria;
ii. Hoehn and Yahr (H&Y) stage I to III in the on-phase of the medication cycle; and
iii. Mini-Mental State Examination (MMSE) >24.

Exclusion criteria were:

i. upper limb medical problems (peripheral neuropathy) which would impede handwriting;
ii. subjects with possibility of atypical parkinsonism, stroke, neuropathy in hands, significant tremors, dystonia- and levodopa-induced dyskinesias;
iii. a history of depression or neurological diseases other than iPD and
iv. deep brain stimulation.

After complete explanation of the study protocol, written informed consent was obtained from the patient prior to participation in the experiment. The medication intake was stable (and no medication change was allowed during the study) and the assessments were always tested at the same time in case of medication fluctuation.

## 5.2 Assessments

### 5.2.1 Handwriting task

The quantification of micrographia was assessed with a handwriting tasks. The subject was asked to write the sentences *"**W**egen meiner **P**arkinson-Erkrankung nehme ich regelmässig bestimmte **M**edikamente ein. **E**s soll nun untersucht werden, ob sich meine **H**andschrift in Zusammenhang mit der **F**DM-Therapie verändert*" at a self determined comfortable size and speed. The same sentence had to be written before and after TMT treatment. Variables included sentence length (cm) (defined as the vector between the beginning and end of both sentences), mean letter height (cm) (defined as the vector between the most upper part and lower part of the six capital letters 'W, P, M, E, H, F' and the writing speed of both sentences assessed by the time per repetition (sec). Surface area ($cm^2$) of the words *Parkinson-Erkrankung*, *Medikamente* and *Handschrift* was calculated by framing the words within a quadrilateral with horizontal and vertical lines parallel to the sides of the sheet. The handwriting tasks were analyzed to evaluate the speed of movement to assess bradykinesia and the size of writing to assess micrographia.

### 5.2.2 Signature

Surface area of the signature ($cm^2$) was calculated by framing the signature within a quadrilateral with horizontal and vertical lines parallel to the sides of the sheet.

### 5.2.3 Motor status

The author assessed the motor status of the included patient. All the assessments were assessed at baseline, two, three, four and eight weeks. All assessments were taken in a quiet room at the Zentrum für Physiotherapie am Markt GmbH, Heerbrugg, Switzerland, while sitting at a table on a height-adjustable chair. The patient was not allowed to train writing skills at any time during the study. Strength of hand- and elbow muscles were assessed by the terms of the medical research council (MRC) and a hand-dynamometer and a pinch-dynamometer. Range of motion was evaluated by the neutral-0-method. Rigidity, finger-tapping, pronation-supination movements of hands, tremor and kinetic tremor of the hands were assessed by using MDS-UPDRS items. All assessments were taken before and after each treatment, altogether nine assessments were evaluated.

## 5.3 Treatment method according to the Fascial Distortion Model (FDM)

The patient was asked to indicate the location of dysfunction in the upper extremity while writing. The diagnosis was derived from the body language (BL) and the description of the patient, using FDM according to Typaldos [24]. The patient was treated once a week. Each treatment lasted maximally 20 minutes. Altogether, the patient was treated four times.

### 5.3.1 Procedure of the treatment

Each intervention included the following handlings:

- Unfolding and refolding manipulations of interosseous membrane, and folding manipulation of intermuscular septum
- Intermuscular septal folding distortions
- Tectonic technique (modified frogleg and reverse frogleg)

- Triggerbands of forearm
- Cylinder distortions of antebrachial fascia, hand and fingertips.

### 5.4 Statistical Evaluation

Descriptive statistics were used to show the characteristics of the sample. A linear trend line was used to analyze the data. The trend line is an optimized straight line that is used for simple linear data sets. The statistical description included the determination of maximum, minimum and mean value's in cm. Data were analyzed using Microsoft® Excel® for Mac 2011, Version 14.6.4.

# 6. Results

## 6.1 General characteristics

One patient (male) with a diagnosed idiopathic Parkinson's Disease (Hoehn & Yahr scale II) participated in the study. The patient was a retired caretaker in St. Gallen, Switzerland. The patient was 67 years old, weighed 81kg, and was 1.87m tall. More specific baseline characteristics are listed below in **table 1**. The average duration of the four treatments was 19.20 minutes. No side effects were recorded. The participant completed all of the writing tasks. All evaluations were performed during the 'On' motor condition.

**Table 1: Baseline characteristics**

| **General data** | |
|---|---|
| Gender | male |
| Age (y) | 67 |
| Height (m) | 1.87 |
| Weight (kg) | 81 |
| Dominant hand | right |
| Disease duration (y) | 8 |
| Most affected side | right |
| MMSE (0-30) | 26 |
| H&Y (0-5) | 2 |
| LED (mg/24h) | Sifrol 1,75 mg<br>Symmetrel 200 mg<br>Madopar 5 mg<br>Madopar DR 125 mg |

**Abbreviations:** H&Y = Hoehn and Yahr stage; h = hours; kg = kilogram; LED = levodopa equivalent dose; mg = milligram; MMSE = Mini Mental State Examination; y = years;

**Table 2: Motor status**

| Motor status (only right side) | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | FU | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| **Strength (MRC) 0-5** | | | | | | | | | | |
| Hand flexion | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4.7 |
| Hand extension | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4.3 |
| Supination | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4.7 |
| Pronation | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 4.7 |
| Elbow flexion | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4.9 |
| Elbow extension | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4.8 |
| Hand-Dynamometer (kg) | 35 | 35 | 37 | 38 | 36 | 32 | 40 | 36.5 | 40 | 36.6 |
| Pinch-Dynamometer (kg) | 8 | 9.5 | 8 | 8.5 | 7.5 | 9.5 | 8.5 | 7.5 | 9 | 8.4 |
| **Range of motion (Neutral-0 Method)** | | | | | | | | | | |
| Hand flexion | 60 | 63 | 75 | 73 | 76 | 74 | 78 | 80 | 85 | 73.8 |
| Hand extension | 88 | 90 | 89 | 88 | 90 | 91 | 87 | 94 | 96 | 90.3 |
| Supination | 79 | 82 | 84 | 84 | 83 | 82 | 85 | 86 | 91 | 84.0 |
| Pronation | 91 | 90 | 91 | 92 | 93 | 90 | 89 | 92 | 94 | 91.3 |
| Elbow flexion | 139 | 140 | 134 | 137 | 133 | 135 | 135 | 137 | 140 | 136.7 |

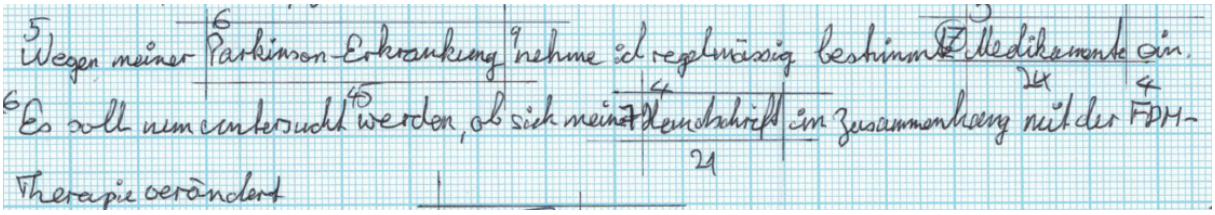
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Hand writing tasks** | | | | | | | | | | |
| Time (sec): | 373 | 292 | 288 | 248 | 301 | 280 | 279 | 263 | 251 | 286.1 |
| Mean letter height (cm): | 0.5 | 0.53 | 0.57 | 0.65 | 0.57 | 0.7 | 0.6 | 0.68 | 0.62 | 0.6 |
| Sentence length (cm): | 38.5 | 37.3 | 48.7 | 48.6 | 38.2 | 48.9 | 48.5 | 49.7 | 53.4 | 45.8 |
| Surface area ($cm^2$) | 7.17 | 6.51 | 10.3 | 10.7 | 7.11 | 12.53 | 11.19 | 12.33 | 12.65 | 10.1 |
| Signature ($cm^2$) | 2.1 | 1.12 | 1.05 | 1.8 | 1.2 | 1.62 | 1.19 | 1.62 | 1.33 | 1.4 |
| **Items from MDS-UPDRS-III** | | | | | | | | | | |
| Rigidity (0-4) | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 1 | 1 | 2.1 |
| Finger Tapping (0-4) | 3 | 2 | 2 | 2 | 3 | 2 | 2 | 1 | 1 | 2.0 |
| Pronation-supination movements of hands (0-4) | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 1 | 1 | 2.1 |
| Tremor (0-4) | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0.7 |
| Kinetic tremor of the hands (0-4) | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 |

**Abbreviations:** $cm^2$ = square centimeter; FU = follow-up; kg = kilogram; MDS-UPDRS-III = Movement Disorders Unified Parkinson's disease rating scale part 3; mm = millimeters; MRC = Medical Research Council; sec = seconds;

### 6.1.1 Handwriting samples (surface area of signature is not shown because of patients privacy). More detailed descriptions are listed in chapter 6.2.

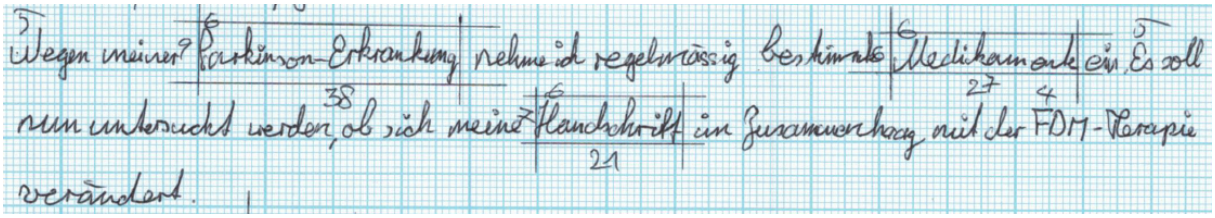
There is an objective change in the handwriting samples 1a to 5a. The writings were initially reduced, slowed down, angle instead of garlands and arcades, slight trembling, reduced bonding degrees and irregularities. After the treatment with TMT the writing speed became faster, and looked firm and round.

#### 6.1.1.1 Handwriting sample 1a



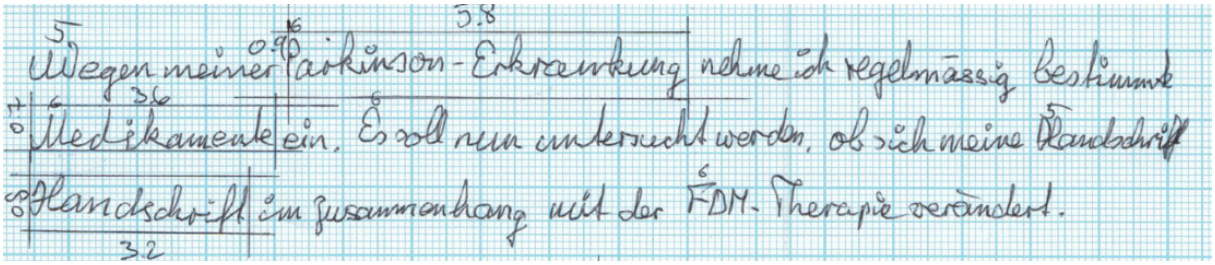
**Picture 1: handwriting sample 1a**

#### 6.1.1.2 Handwriting sample 1b



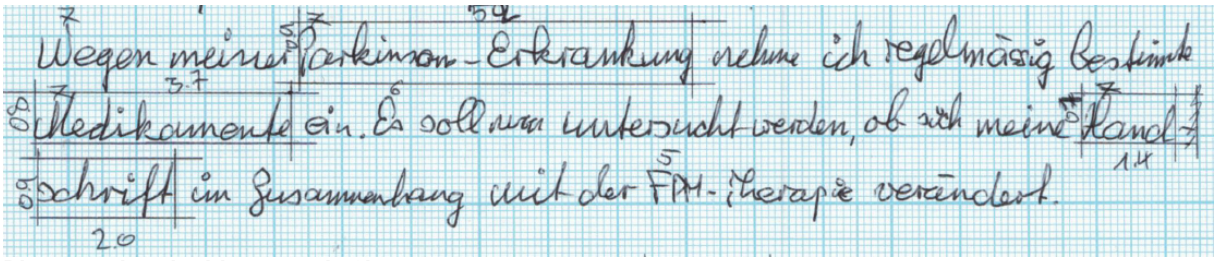
**Picture 2: handwriting sample 1b**

#### 6.1.1.3 Handwriting sample 2a



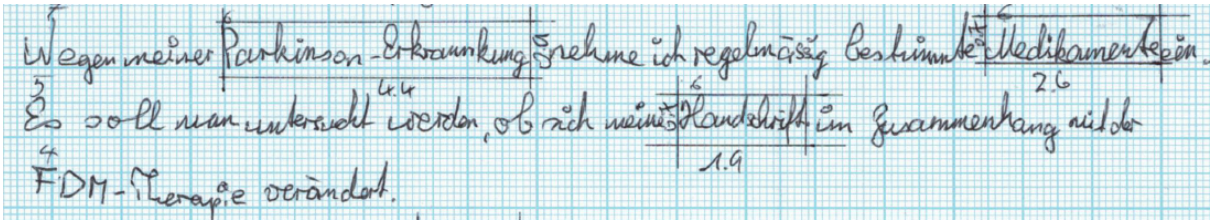
**Picture 3: handwriting sample 2a**

### 6.1.1.4 Handwriting sample 2b



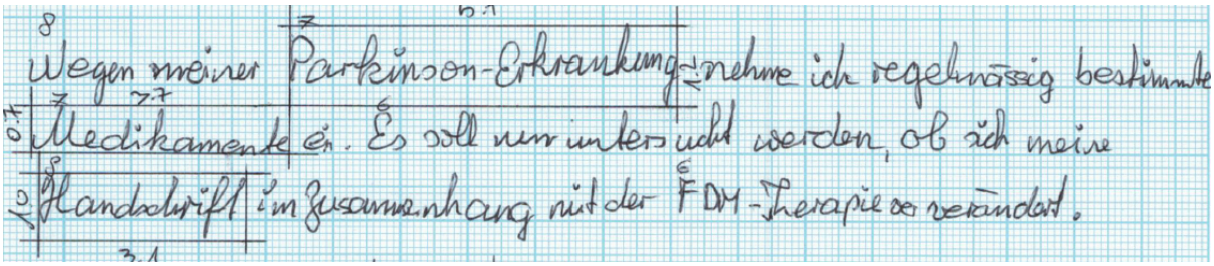
**Picture 4: handwriting sample 2b**

### 6.1.1.5 Handwriting sample 3a



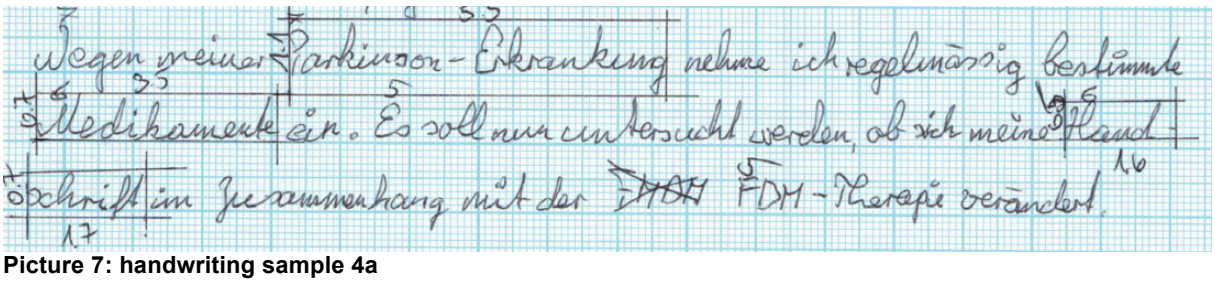
**Picture 5: handwriting sample 3a**

### 6.1.1.6 Handwriting sample 3b



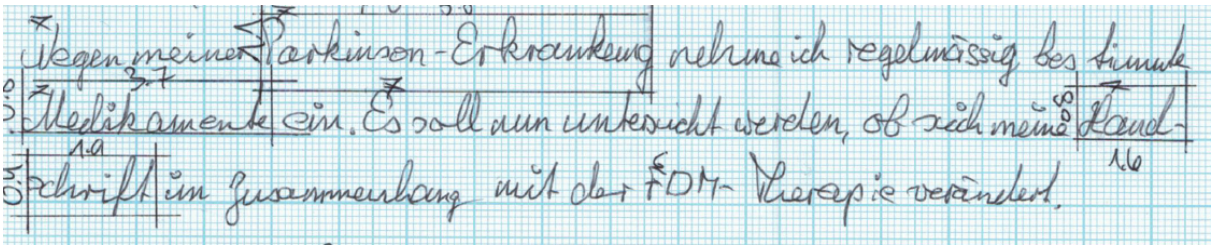
**Picture 6: handwriting sample 3b**

### 6.1.1.7 Handwriting sample 4a



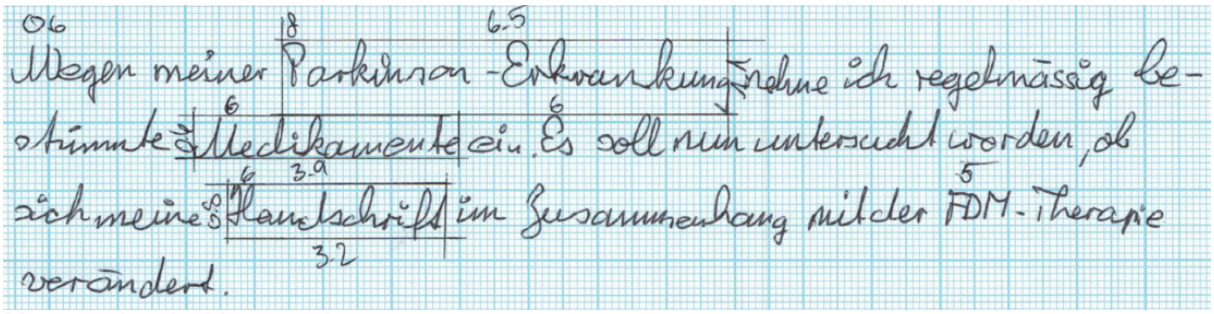
**Picture 7: handwriting sample 4a**

### 6.1.1.8 Handwriting sample 4b



**Picture 8: handwriting sample 4b**

### 6.1.1.9 Handwriting sample 5a (Follow up)



**Picture 9: handwriting sample 5a**

## 6.2 Measurement 1a and b

Strength (MRC) changed only in elbow flexion (4/5) and pinch-Dynamometer (8/9.5 kg). Only small change in range of motion was observed. The time for the writing task decreased from 373 to 292 sec. Mean letter height increased from 0.50 to 0.53 cm. Sentence length decreased from 38.5 to 37.3 cm. The surface area decreased from 7.17 to 6.51 $cm^2$. Signature area decreased from 2.1 to 1.12 $cm^2$. Rigidity (3/3), pronation-supination movements of hands (3/3), tremor (1/1) showed no changes. Finger Tapping (3/2) and kinetic tremor of the hands (2/1) improved.

## 6.3 Measurement 2a and b

Strength (MRC) increased in hand flexion (4/5), supination (4/5), pronation (4/5), hand-dynamometer (37/38kg) and pinch-dynamometer (8/8.5kg). Only small change in range of motion was observed. Time for the writing task improved from 288 to 248 sec. Mean letter height increased from 0.57 to 0.65 cm. The sentence length de-

creased slightly from 48.7 to 48.6 cm. Surface area increased from 10.3 $cm^2$ to 10.7 $cm^2$. Signature area increased from 1.05 to 1.8 $cm^2$. Rigidity (2/2), finger tapping (2/2), pronation-supination movements of hands (2/2) and tremor (1/1) were stable. Kinetic tremor of the hands (1/0) was improved.

### 6.4 Measurement 3a and b

The strength of the patient (MRC) decreased from 36 to 32 kg measured by the hand-dynamometer and increased from 7.5 to 9.5 kg, measured by the pinch-dynamometer. Only small improvement in range of motion was observed. The time for the writing task decreased from 301 sec to 280 sec. Mean letter height increased from 0.57 to 0.7 cm. Sentence length decreased from 38.2 to 48.9 cm. Surface area increased from 7.17 to 12.53 $cm^2$. Signature area increased from 1.2 to 1.62 $cm^2$. Rigidity increased (2/3), pronation-supination movements of hands (3/2) and finger tapping (3/2) decreased, tremor (1/1) and kinetic tremor of hands (0/0) showed no changes.

### 6.5 Measurement 4a and b

The strength of the patient (MRC) measured by the hand-dynamometer decreased from 40 to 36.5 and 8.5 to 7.5 kg, measured by the pinch-dynamometer. Only small changes in range of motion were observed. The time for the writing task decreased from 279 sec to 263 sec. Mean letter height increased from 0.6 to 0.68 cm. Sentence length decreased from 48.5 to 49.7 cm. Median surface area increased from 11.19 to 12.33 $cm^2$. Signature area increased from 1.19 to 1.62 $cm^2$. Only rigidity (2/1), finger tapping (2/1) and pronation-supination movements of hands (2/1) decreased.

## 6.6 Measurement 5 (Follow-up)

The results of measurement 5 were compared to the last measurement 4b to evaluate long-term effects. The strength of the patient (MRC) measured by the hand-dynamometer increased from measurement 4b from 36.5 to 40 kg, respectively from 7.5 to 9 kg (pinch-dynamometer). Only slight improvements were seen in the range of motion. The time for the writing task decreased from 263 to 251 sec. Mean letter height decreased from 0.68 to 0.62 $cm^2$. Sentence length improved from 49.7 to 53.4 cm. Surface area increased from 12.33 to 12.65 $cm^2$. Signature decreased from 1.62 to 1.33 $cm^2$. All items from the MDS-UPDRS-III remained stable.

## 6.7 Time for the handwriting task

The time for the writing task decreased steadily from M1a to M5 (FU) ($R^2$ = 0.66). After each treatment, the speed increased (M1b-M4b), but there was no linear correlation ($R^2$ = 0.14).

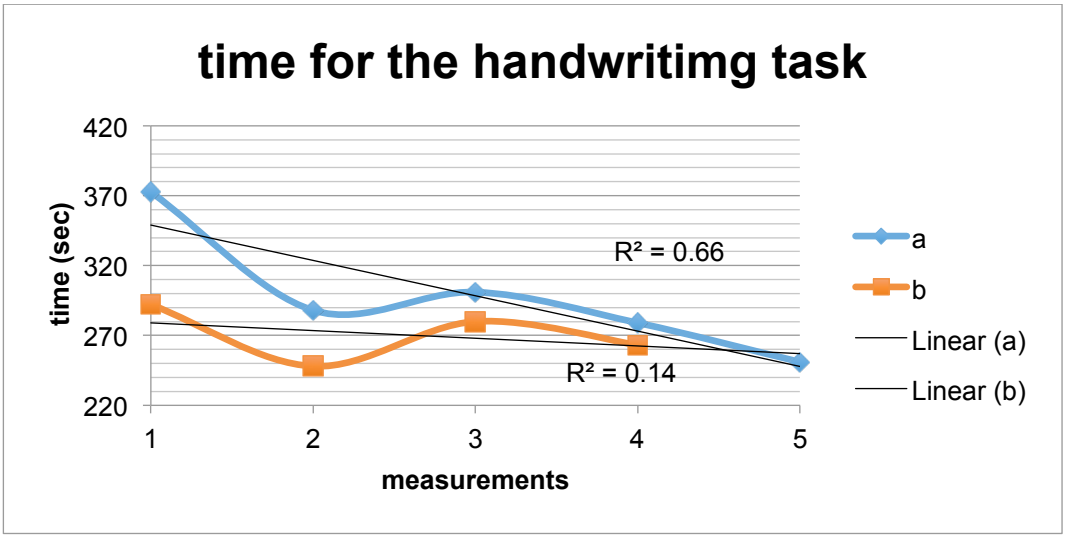



**Diagram 1: time**

## 6.8 Mean letter height

Mean letter height was always bigger after each treatment (M1b to M4b), $R^2$ = 0.72). In general, patients' letter height increased steadily from M1a up until the follow-up ($R^2$ = 0.88).

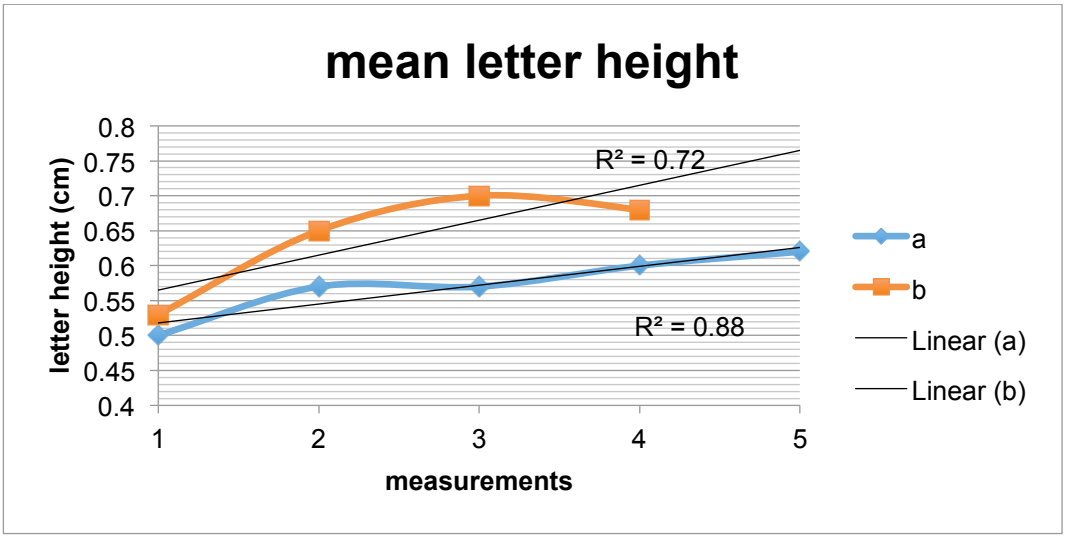



**Diagram 2: mean letter height**

## 6.9 Sentence length

After M2, sentence length was longer after each treatment ($R^2$ = 0.67). A small elongation of the sentences can be seen in M1a to M5 ($R^2$ = 0.48).

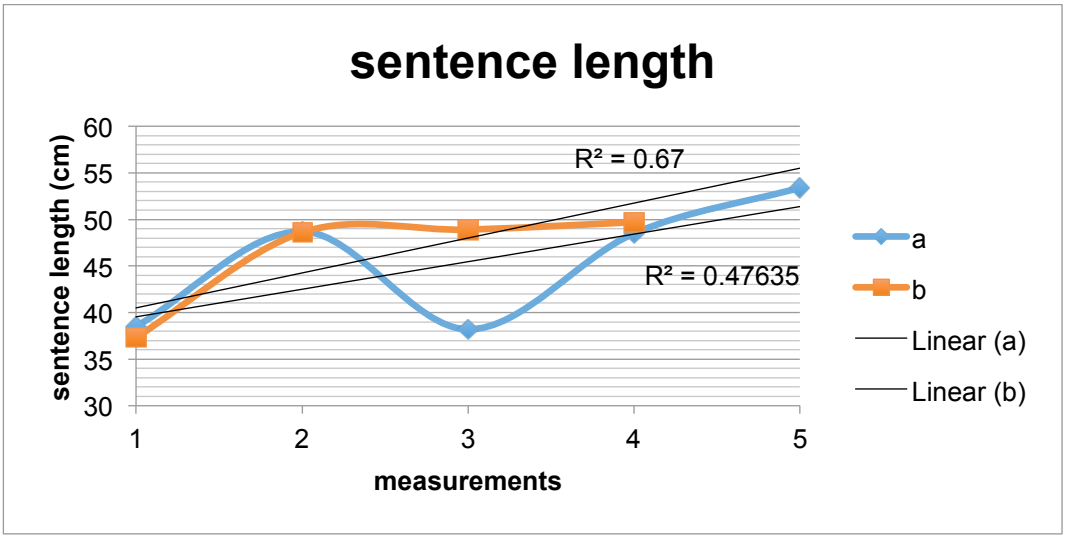



**Diagram 3: sentence length**

## 6.10 Surface area

Surface area increased after each treatment ($R^2$ = 0.79). In general, a small but non-linear ($r^2$ = 0.29) increase in size is shown.

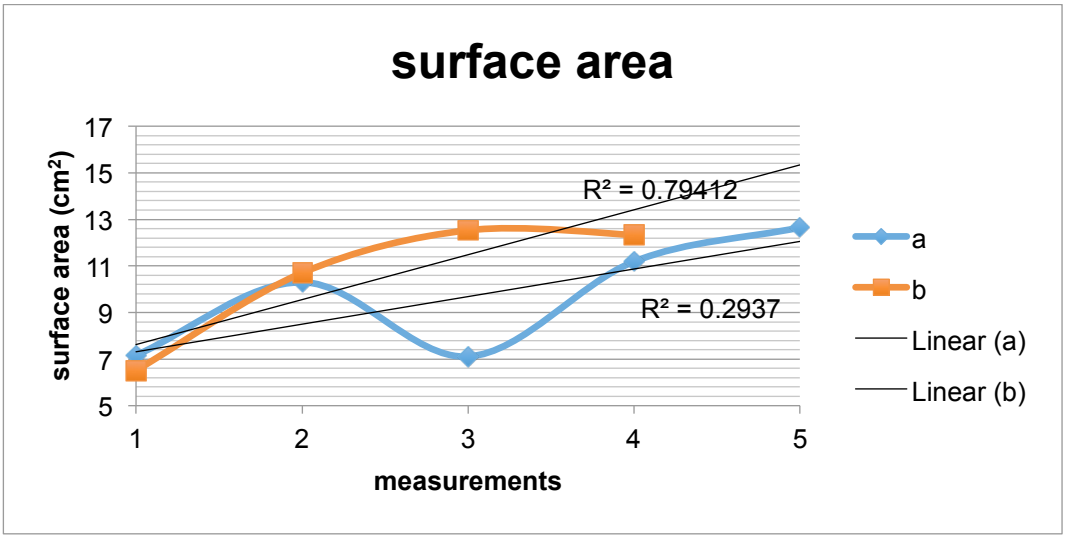



**Diagram 4: surface area**

## 6.11 Signature

Signature was bigger after each treatment (M2b to M4b, $R^2 = 0.34$). M1a to M5 showed a small correlation (R2 = 0.48) in the increase of the size.

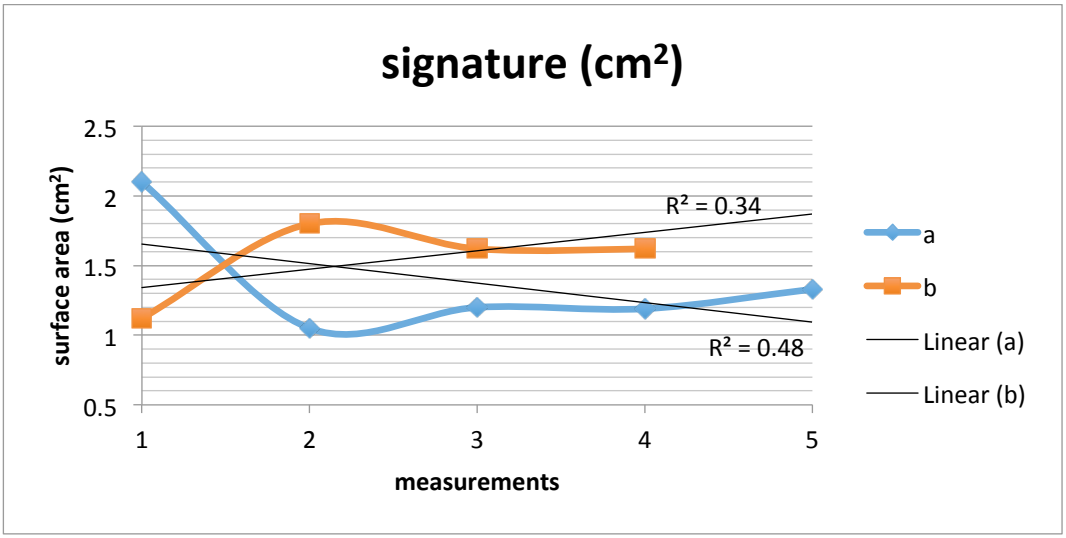



**Diagram 5: signature**

In reason of of small evident changes and better readability the data of strength and range of motion are shown in the appendix. See 10.1 for strength, diagram 1-13 and see 10.2 range of motion, diagram 14-19. Further details about MDS-UPDRS items are shown in 10.3, MDS-UPDRS-items, table 3-7 and Hoehn & Yahr scale is shown in 10.3.6, table 8.

# 7. Discussion

The aim of the current pilot case study was to investigate the effects of FDM in micrographia in idiopathic Parkinson's disease. In this study, FDM was associated with an improvement in most of the graphological variables assessed. These changes were evident for handwriting tasks (time per repetition, mean letter height, sentence length, surface area and signature). Writing size was examined to find objective measures for micrographia. Surprisingly, all of the items from MDS-UPDRS-III (rigidity, finger tapping, pronation-supination movements of hands, tremor and kinetic tremor of the hands) improved in short-term and long-term measurements.

In our sample the writings were initially reduced, slowed down, angle instead of garlands and arcades, slight trembling, reduced bonding degrees and irregularities. After the first treatment with TMT the writing speed became faster, and looked firm and round. These results showed, that TMT is a fast and effective treatment to improve micrographia and change motor dysfunctions caused by iPD. Furthermore, this is a pilot study where long-term follow-up was recorded and the results showed improvements even without intervention. Moreover the method is very stressful for the patient, any side effects were recorded.

One of the limitations of this study was the small sample size, which limits the number of statistically significant results and the generalization. A direct comparison with alternative treatments was impossible because of the chosen study design. This study has some further limitations. First, we measured only sentence length and letter height and surface areas. Other writing kinematics such as amplitude of maximum velocity and the number of movement units should be examined in future research to provide information on the force and smoothness of handwriting. Second, we had the paper aligned horizontally and vertically and maybe helped the patient's orientation.

Third, although the patient was always tested at the same time, patient's medication intake was not always exactly and could interfere with the patient's performance. Fourth, however, the clinical tests from the items of MDS-UPDRS-III were difficult to assess. The rigidity, as an example, is a symptom, which is very hard to quantify, because it refers to an increased muscle tone noticed during subjective assessment by a physician during passive movements of, for example, an affected arm. Fifth, this study was not blinded. The author of this study treated the patient and evaluated the data. And last, the reproduction of the manual treatment is very difficult. There is no advice for measuring treatment pressure and forces onto the fascial tissues.

## 7.1 Bottom-up-Theory: a new hypothesis of the genesis of idiopathic Parkinson's disease

Until now, the pathophysiology of iPD remains unclear. This pilot case study sheds some light onto a new hypothesis of the genesis of iPD. Different findings demonstrated that consistent micrographia is related to dysfunction of the basal ganglia motor circuit; while a combination of dysfunction of the basal ganglia motor circuit and disconnection of the pre Supplementary motor area (pre-SMA), rostral cingulate motor area (rCMA) and cerebellum is associated with progressive micrographia. In the study of Wu et al. writing in iPD was associated with activations in the left primary motor area, left pre-SMA and caudal SMA, right rCMA, bilateral premotor cortex (PMC), left ventral PMC, right superior parietal lobule (SPL), bilateral inferior parietal lobule (IPL), left putamen, left thalamus, left fusiform gyrus and bilateral cerebellum [11].

Handwriting is a well-habituated, coordinated motor skill which has been exercised for many years. Although writing can be considered a visually controlled motor task, it

also consists of highly automatically performed features, including writing size and consistency [25]. In the study of Wu et al. writing in iPD was associated with activations in the left primary motor area, left pre-SMA and caudal SMA, right rCMA, bilateral PMC, left ventral PMC, right superior parietal lobule (SPL), bilateral inferior parietal lobule (IPL), left putamen, left thalamus, left fusiform gyrus and bilateral cerebellum. These mechanisms are described as a top-down-theory. On the basis of aging and former distortions, the ability of the radio-ulnar interosseous membrane to unfold and refold decreases, not affecting patient's ADL and remains unobserved. Due to this lack of movement, signals to the brain weaken. Therefore, cells in the substantia nigra shrink slowly because of the principle of „use it or lose it". This slight alteration is clinically not relevant until approx. 80% of the cells of the substantia nigra have perished and clinical symptoms such as bradykinesia and rigidity emerge. These mechanisms could be described as a bottom-up-theory. Stephen Typaldos wrote in his book that from the FDM perspective supination and pronation of the forearm are to a large extent made possible by the ability of the radio-ulnar interosseous membrane to unfold and refold. In the FDM, muscle movement of any kind (even spasm, tremor, or hypertonia) is considered to be triggered by signals from the brain commanding that muscle to move. And since fascia acts as a mechanical sensory system, cylinder distortions cause an uneven pull of the coils which is registered in the nervous system as unequal tension. The uneven mechanical pull varies each instance of muscle contraction since the coils rotate with contraction, pronation or supination. This sends constant but geographically changing inequalities of mechanical tension sensory input to the brain from very closely adjacent areas [23]. So far there is no cure, because the root cause of the dying off of the nerve cells is unknown, despite intensive research.

## Conflict of interest

No potential conflict of interest relevant to this article was reported.

## 8. Conclusion

### 8.1 Impact on clinical practice

The results of this clinical study show that the treatment method according to the fascial distortion model is a low-priced, rapid and effective option to ameliorate writing performance and even motor symptoms (rigidity and bradykinesia) in a patient with iPD. Until now, there exists no specific manual treatment for improving micrographia in iPD-patients. Therefore, we suggest that FDM may be helpful in improving handwriting difficulties among iPD patients. Due to the fact that the genesis of iPD still remains unclear, this new approach can lead to a better understanding of the pathological process and change the point of view. If larger randomized studies confirm these results, FDM should be included in the multidisciplinary approach necessary for iPD management.

### 8.2 Impact on future research

In line with this approach, we also suggested that computerized analysis of handwriting movements represents a simple, noninvasive and useful tool that can contribute to both iPD diagnosis and follow-up for clinicians who deal with iPD micrographia. Taken together, these findings turn iPD micrographia into a reliable physiological biomarker for the early detection of iPD. Future research with a larger sample size will be important for detecting potential differences that may provide alternative explanations for the effect of FDM and handwriting observed in this study. To improve methodological quality, the study should be triple blinded, this means that one researcher

should treat the patient's forearm with TMT, another should extract the data from the handwriting tasks and the third researcher should evaluate the gathered data.

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# 10. Appendix

## 10.1 Strength

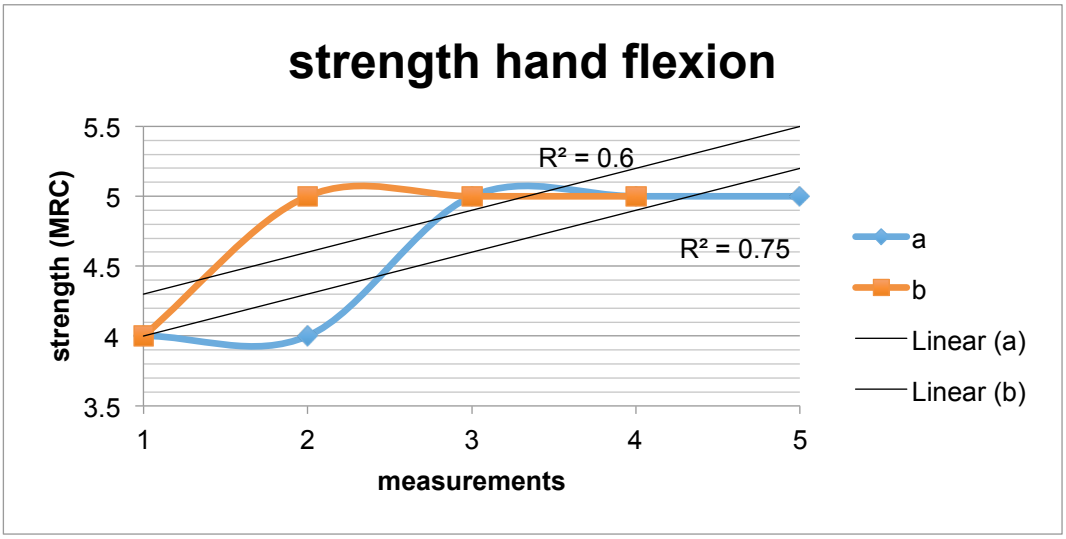


**Diagram 6: strength hand flexion**

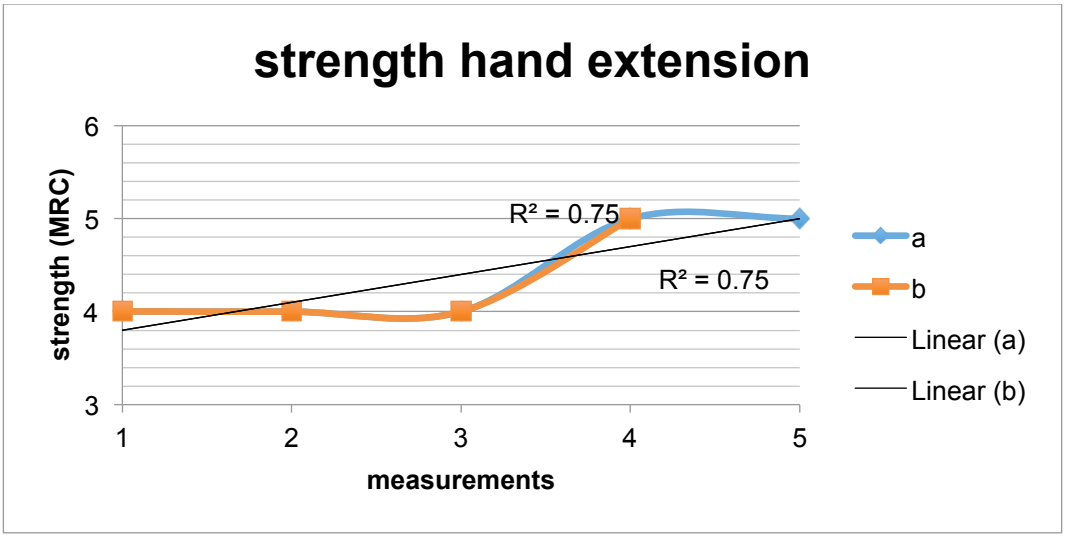


**Diagram 7: strength hand extension**

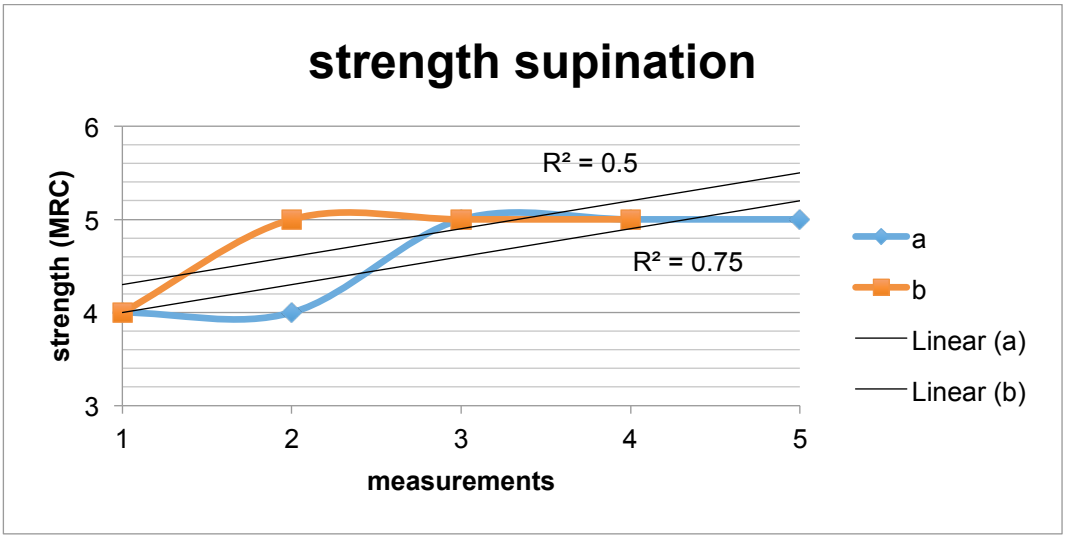


**Diagram 8: strength supination**

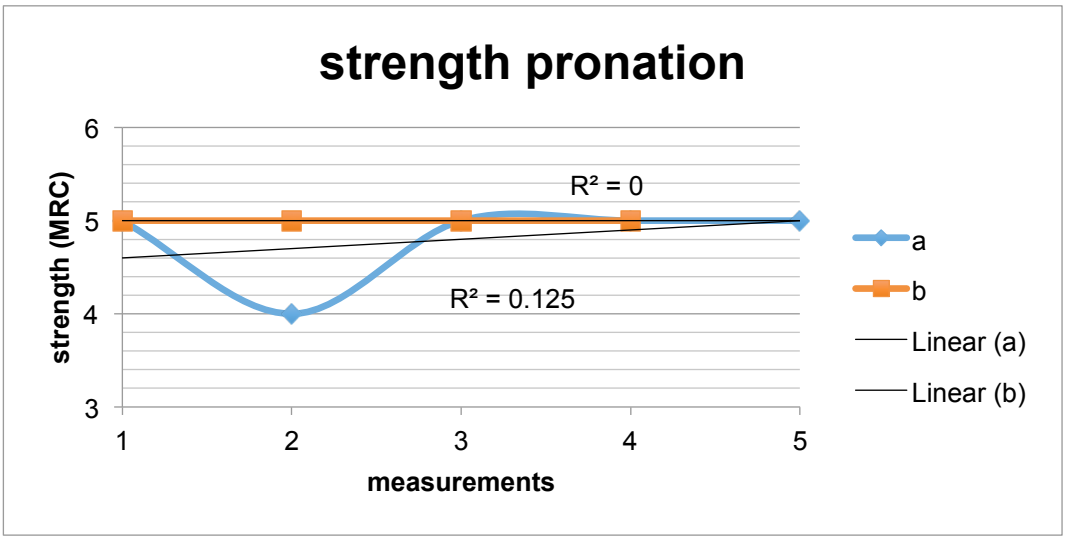


**Diagram 9: strength pronation**

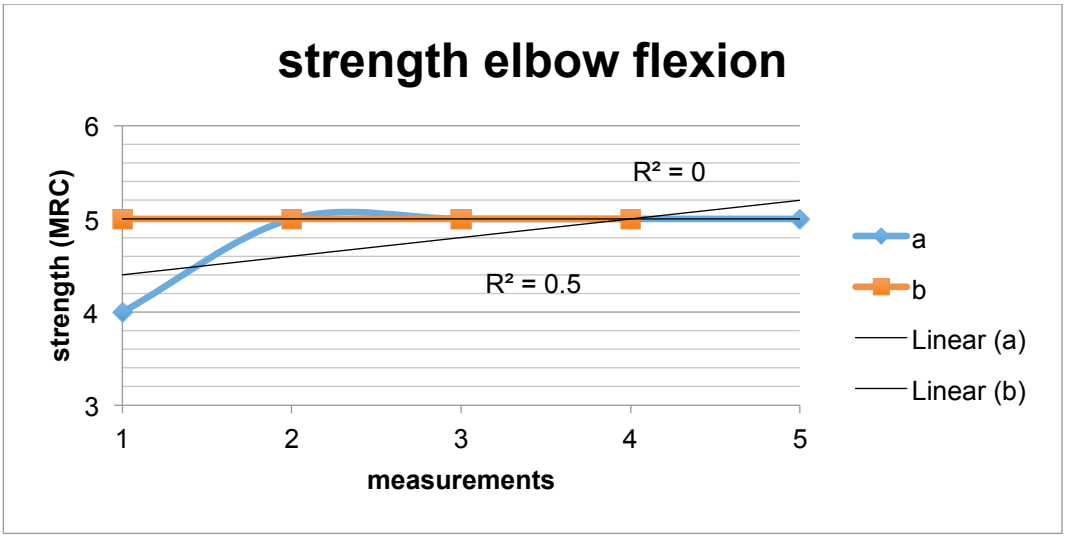

**Diagram 10: strength elbow flexion**

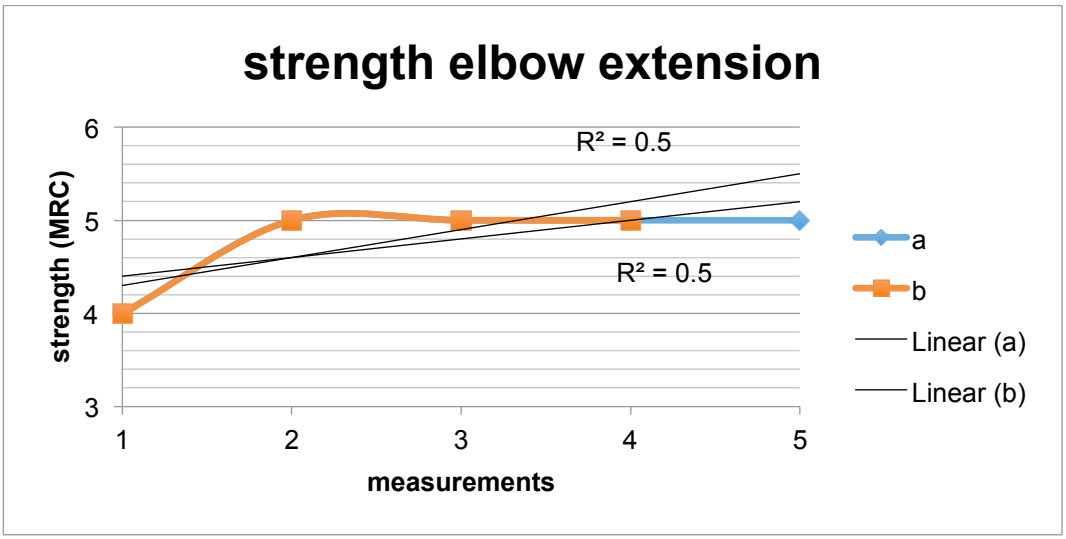


**Diagram 11: strength elbow extension**

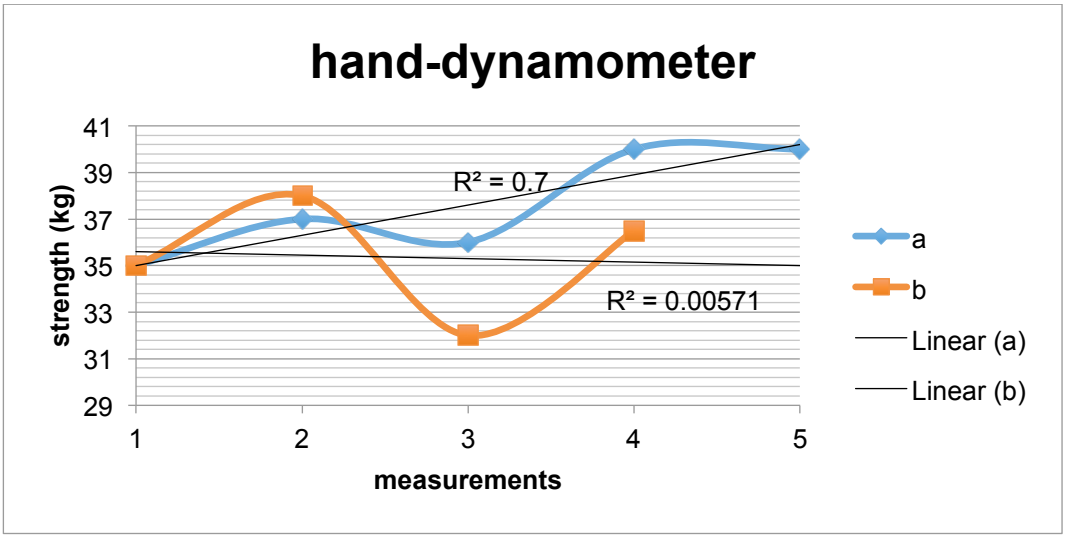


**Diagram 12: hand-dynamometer**

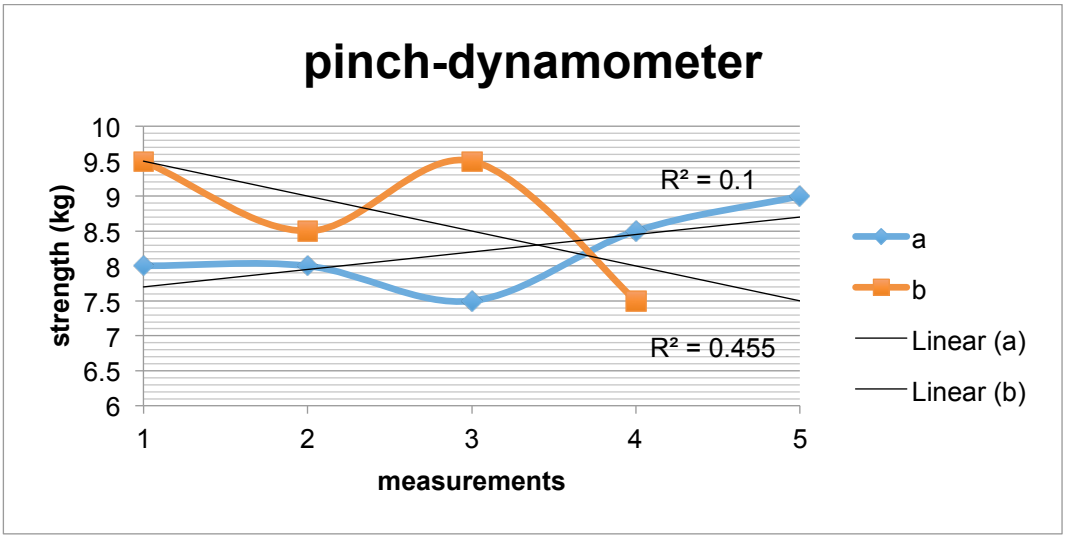


**Diagram 13: pinch-dynamometer**

## 10.2 Range of motion

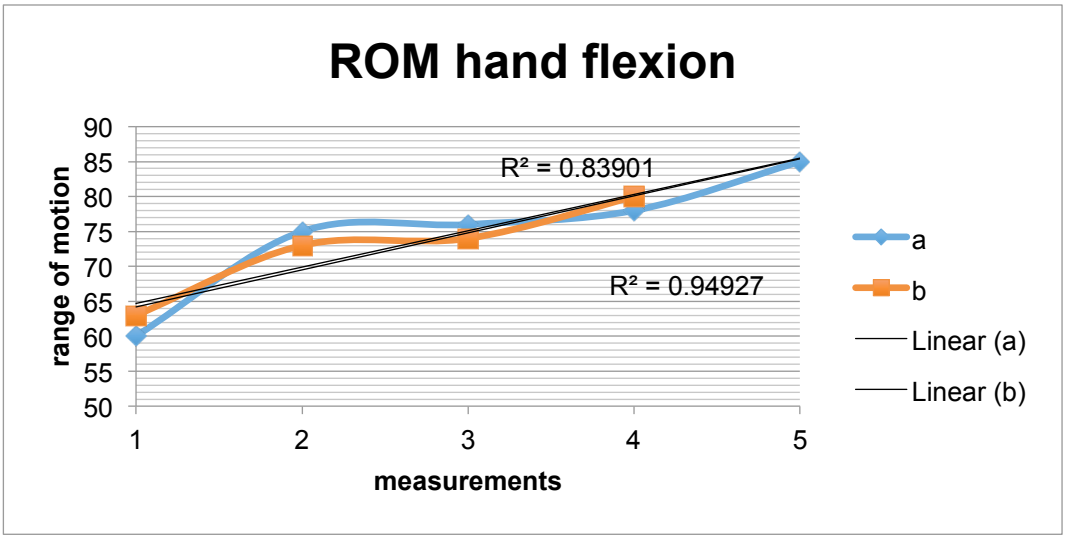


**Diagram 14: ROM hand flexion**

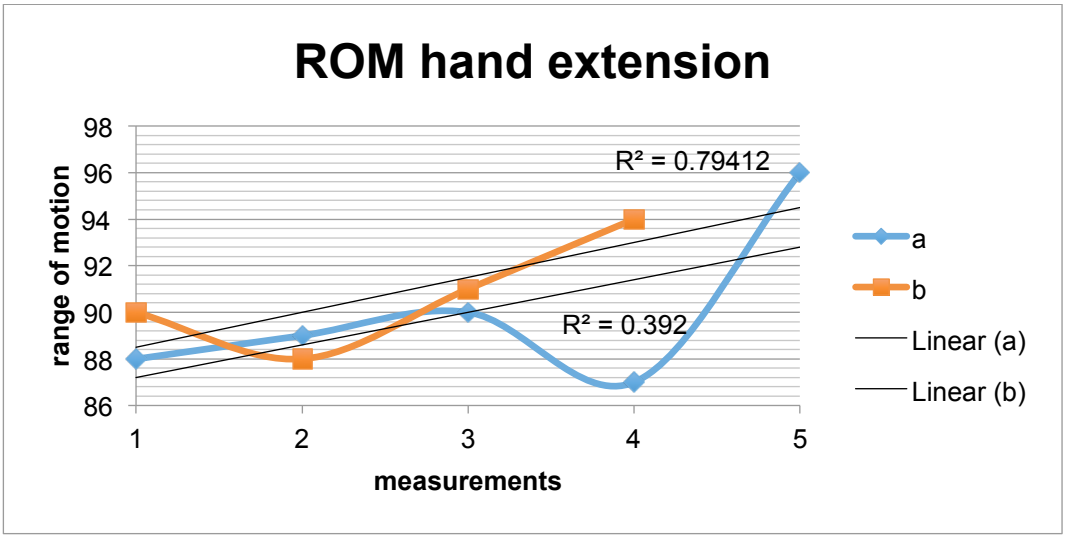


**Diagram 15: ROM hand extension**

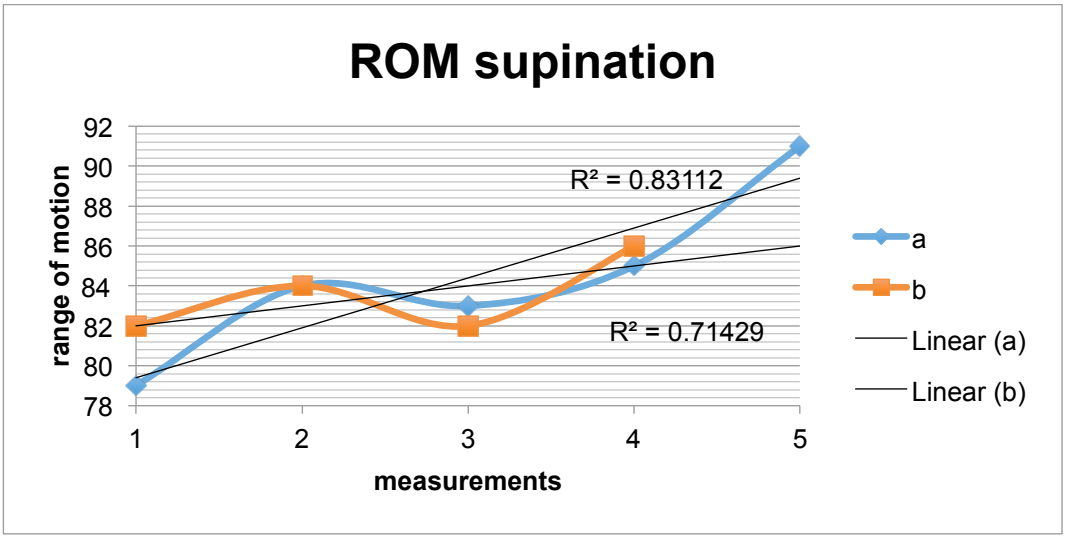


**Diagram 16: ROM supination**

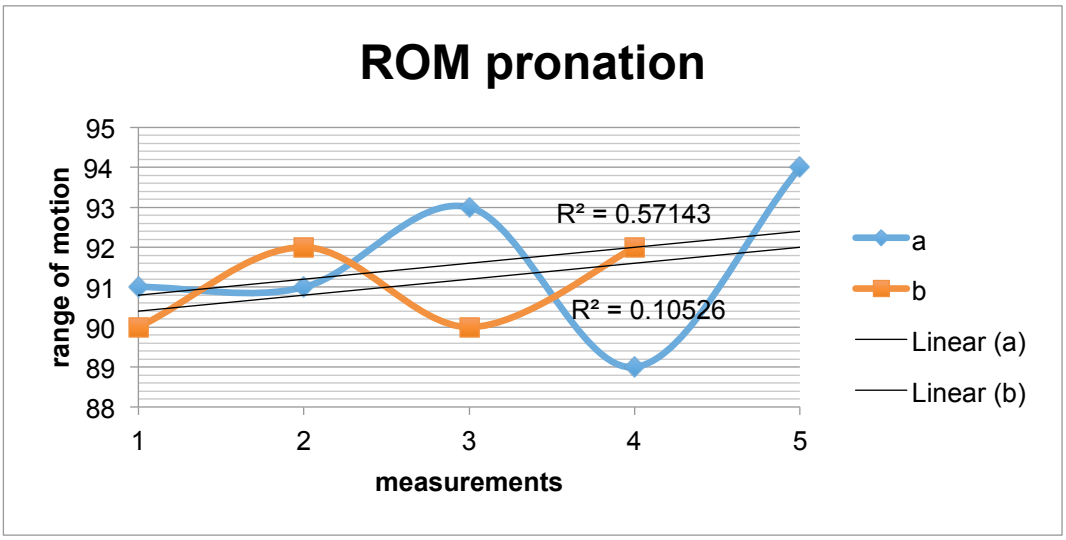


**Diagram 17: ROM pronation**

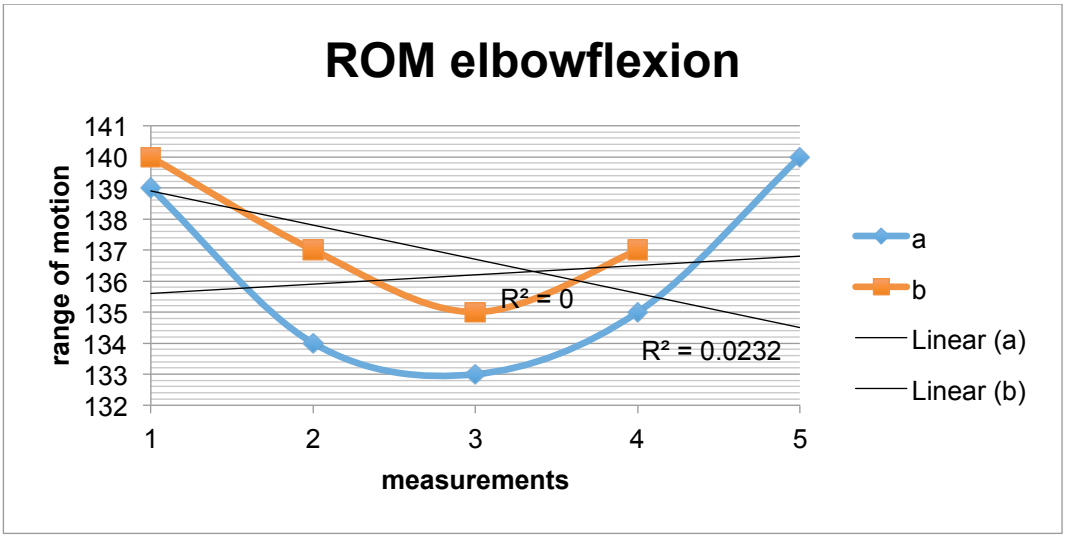

**Diagram 18: ROM elbow flexion**

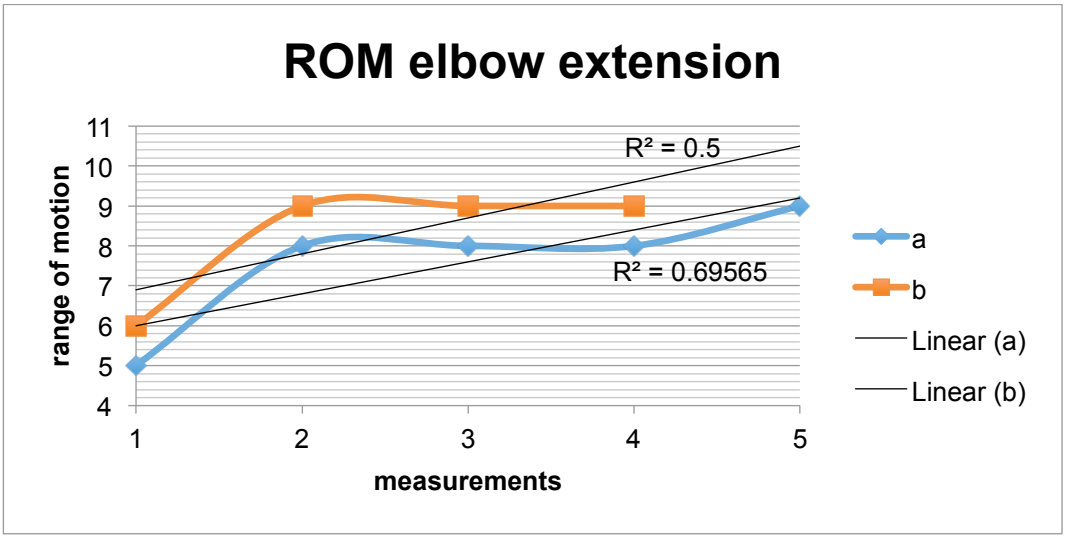


**Diagram 19: ROM elbow extension**

## 10.3 MDS-UPDRS items

### 10.3.1 Rigidity MDS-UPDRS item 3.3

Rigidity is judged on slow passive movement of major joints with the patient in a relaxed position and the examiner manipulating the limbs and neck.

| | |
|---|---|
| 0: Normal: | No rigidity. |
| 1: Slight: | Rigidity only detected with activation maneuver. |
| 2: Mild: | Rigidity detected without the activation maneuver, but full range of motion is easily achieved. |
| 3: Moderate: | Rigidity detected without the activation maneuver; full range of motion is achieved with effort. |
| 4: Severe | Rigidity detected without the activation maneuver and full range of motion not achieved |

**Table 3: Rigidity MDS-UPDRS item 3.3**

### 10.3.2 Finger Tapping MDS-UPDRS item 3.4

Each hand was tested separately. The physician demonstrated the task, but did not continue to perform the task while the patient was being tested. The patient was instructed to tap the index finger on the thumb ten times as quickly AND as big as possible. Each side was rated separately, evaluating speed, amplitude, hesitations, halts and decrementing amplitude.

| | |
|---|---|
| 0: Normal: | No problems. |

| | |
|---|---|
| 1: Slight: | Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the tapping movement; b) slight slowing; c) the amplitude decrements near the end of the 10 taps. |
| 2: Mild: | Any of the following: a) 3 to 5 interruptions during tapping; b) mild slowing; c) the amplitude decrements midway in the 10-tap sequence. |
| 3: Moderate: | Any of the following: a) more than 5 interruptions during tapping or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1st tap. |
| 4: Severe: | Cannot or can only barely perform the task because of slowing, interruptions or decrements. |

**Table 4: Finger Tapping MDS-UPDRS item 3.4**

### 10.3.3 Pronation-supination movements of hands MDS-UPDRS item 3.6

Each hand was tested separately. The task was demonstrated, but not continued to perform the task while the patient was being tested. The patient was instructed to extend the arm out in front of his/her body with the palms down; then to turn the palm

up and down alternately ten times as fast and as fully as possible. Each side was tested separately, evaluating speed, amplitude, hesitations, halts and decrementing amplitude.

| | |
|---|---|
| 0: Normal: | No problems. |
| 1: Slight: | Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the movement; b) slight slowing; c) the amplitude decrements near the end of the sequence. |
| 2: Mild: | Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowing; c) the amplitude decrements midway in the sequence. |
| 3: Moderate: | Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing c) the amplitude decrements starting after the 1st supination-pronation sequence. |
| 4: Severe: | Cannot or can only barely perform the task because of slowing, interruptions or decrements. |

**Table 5: Pronation-supination movements of hands MDS-UPDRS item 3.6**

### 10.3.4 tremor MDS-UPDRS item 2.10

Over the past week, have you usually had shaking or tremor?

| | |
|---|---|
| 0: Normal: | Not at all. I have no shaking or tremor. |
| 1: Slight: | Shaking or tremor occurs but does not cause problems with any activities. |
| 2: Mild: | Shaking or tremor causes problems with only a few activities. |
| 3: Moderate: | Shaking or tremor causes problems with many of my daily activities. |
| 4: Severe: | Shaking or tremor causes problems with most or all activities. |

**Table 6: Tremor MDS-UPDRS item 2.10**

### 10.3.5 Kinetic tremor of the hands MDS-UPDRS item 3.16

This is tested by the finger-to-nose maneuver. With the arm starting from the out-stretched position, have the patient perform at least three finger-to-nose maneuvers with each hand reaching as far as possible to touch the examiner's finger. The finger-to-nose maneuver was performed slowly enough not to hide any tremor that could occur with very fast arm movements. Repeated with the other hand, each hand was rated separately. The highest amplitude was rated.

| | |
|---|---|
| 0: Normal: | No tremor. |
| 1: Slight: | Tremor is present but less than 1 cm in amplitude. |
| 2: Mild: | Tremor is at least 1 but less than 3 cm in |

| | |
|---|---|
| | amplitude. |
| 3: Moderate: | Tremor is at least 3 but less than 10 cm in amplitude. |
| 4: Severe: | Tremor is at least 10 cm in amplitude. |

**Table 7: Kinetic tremor of the hands MDS-UPDRS item 3.16**

### 10.3.6 Hoehn and Yahr stage

| |
|---|
| 0: Asymptomatic. |
| 1: Unilateral involvement only. |
| 2: Bilateral involvement without impairment of balance. |
| 3: Mild to moderate involvement; some postural instability but physically independent; needs assistance to recover from pull test. |
| 4: Severe disability; still able to walk or stand unassisted. |
| 5: Wheelchair bound or bedridden unless aided. |

**Table 8: Hoehn and Yahr stage**

## 10.3.6 Letter of Content

**Einverständniserklärung**

Name [redacted]

Geburtsdatum 27.8.1948

Das Original dieser Einwilligungserklärung verbleibt bei den Studienunterlagen. Eine Kopie wird dem Probanden ausgehändigt.

Ich [redacted]
(Name, Vorname)

erkläre, dass ich die Probandeninformation zur Studie:

und diese Einwilligungserklärung zur Studienteilnahme erhalten habe.

(x) Ich wurde für mich ausreichend mündlich und schriftlich über die wissenschaftliche Untersuchung informiert.

(x) Ich weiss, dass ich jederzeit meine Einwilligung, ohne Angaben von Gründen, widerrufen kann, ohne dass dies für mich nachteilige Folgen hat.

(x) Ich bin damit einverstanden, dass die im Rahmen der wissenschaftlichen Untersuchung über mich erhobenen Krankheitsdaten sowie meine sonstigen mit dieser Untersuchung zusammenhängenden personenbezogenen Daten aufgezeichnet werden. Es wird gewährleistet, dass mein personenbezogenen Daten nicht an Dritte weitergegeben werden. Bei der Veröffentlichung in einer wissenschaftlichen Zeitung wird aus den Daten nicht hervorgehen, wer an dieser Untersuchung teilgenommen hat. Meine persönlichen Daten unterliegen dem Datenschutzgesetz.

( x) Mit der vorstehend geschilderten Vorgehensweise bin ich einverstanden und bestätige dies mit meiner Unterschrift.

| Ort | Datum | Patient |
|---|---|---|
| Heerbrugg | 15.6.16 | |
| Ort | Datum | Therapeut |
| Heerbrugg | 15.6.16 | |