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Faculteit Geneeskunde en Levenswetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Feasibility and reliability of a robotic assessment of finger proprioception using a gauge position matching task in stroke and healthy subjects

Toon Clement
Naomi Trekels

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen

PROMOTOR :
dr. Ilse LAMERS

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Prof. dr. Peter FEYS

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Acknowledgement

It is a great pleasure to acknowledge our deepest thanks to Prof. Dr. Peter Feys and Dr. Ilse Lamers for suggesting the topic of this study and their kind supervision.
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Special thanks to Prof. Dr. Olivier Lambercy and Dr. Mike Rinderknecht of ETH Zürich, Rehabilitation Engineering Lab of Zürich, for helping us getting familiar with the device and letting us use the robotic device, named MIKE (Motor Impairment and Kinesthetic Evaluation).

We would like to thank Marc Michielsen and Heidi Jannis, our contact persons of the JESSA rehabilitation center St.-Ursula Herk-de-Stad and the MS rehabilitation center Overpelt.
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Finally, we would like to thank all those who helped us throughout the process of this study.

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Research context

This master thesis fits in the research domain of neurological rehabilitation. Patients with stroke often suffer from motor impairments, cognitive deficits as from somatosensory impairments. It's well known under clinicians that somatosensory is an important predictor for recovery of sensorimotor function (Winward, Halligan, & Wade, 1999). This study will focus on proprioceptive dysfunction, one of the somatosensory sensations. Rinderknecht, Popp, Lambercy, & Gassert (2016) states that quantitative assessments of position sense are essential for the investigation of proprioception, as well as for diagnosis, prognosis and treatment planning for subjects with somatosensory deficits (Pumpa, Cahill, & Carry, 2015; Dukelow et al., 2010). This observational cross-sectional study investigates the feasibility and reliability of a rapid robotic assessment of finger proprioception using a passive gauge position matching tasks in stroke and healthy subjects.

The robotic device used in this study, named MIKE (Motor Impairment and Kinaesthetic Evaluation) is designed by Dr. Mike Rinderknecht and Prof. Dr. Olivier Lambercy from the RELab, ETH Zurich in Switzerland. RELab is a rehabilitation engineering laboratory and has competences in mechanical and electrical engineering, movement science, psychology and neuroscience. RELab applies robotics to the assessment and restoration of sensorimotor function and develop assistive technologies for the compensation of remaining deficits. There is a collaboration between REVAL (Rehabilitation Research Center in Diepenbeek) and RELab ETH Zurich. RELab ETH Zurich (https://www.ethz.ch/de.html) has lent the MIKE in order to measure the reliability of the robot in a stroke, multiple sclerosis and healthy population.

The robot arrived in November at REVAL. There was a two-day session to get familiar with the robot. The measurements and recruitment of subjects taken place in JESSA rehabilitation center St.-Ursula Herk-de-Stad was done by Naomi Trekels and Joke Raats and in the MS rehabilitation center Overpelt by Toon Clement. The data-analysis, statistics and writing of the article was done by Toon Clement and Naomi Trekels. This master thesis was supervised by Dr. Ilse Lamers and Dra. Joke Raats.

For this double master thesis, the central format was applied.

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1. Abstract

Background: Repeatable sensory stimuli can be provided by robotic devices which can be used as an objective and quantitative tool to assess proprioception. A good evaluation of proprioception is essential for diagnosis, prognosis and treatment planning. Despite the development of various robotic tools, their feasibility and reliability in a stroke population are poorly evaluated and reported.

Objectives: To investigate the feasibility and reliability of MIKE, a rapid robotic assessment of finger proprioception using a passive gauge position matching task in stroke and healthy subjects.

Methods: Thirteen stroke participants (mean age 67.3 ± 10.5, 7 male and 6 female) and thirteen healthy participants (mean age 66.5 ± 10.5 years, 7 male and 6 female) were recruited to execute the protocol on two or three consecutive days. The first day the descriptive measures were collected, while on day two and three the proprioception in the index finger was assessed by the robotic device, MIKE. Four proprioceptive outcome measures were calculated based on the data collected by the MIKE in both groups.

Results: The mean score of the System Usability Scale of the stroke group is 75.8 ± 4.25 (95% CI= 66.5-85.0). There was poor to excellent agreement of the most affected hand in the stroke group between sessions with ICC values for the E (0.59-0.89), CE (0.74-0.93), AE (0.55-0.90) and VE (0.32-0.86). There was moderate to excellent within session reliability for both hands. Poor to excellent between and within session reliability was found for the healthy group.

Conclusion: MIKE is a feasible device to measure proprioception in a stroke and healthy population. There was good to excellent between and within session reliability found for both hands in the stroke group. Therefore, MIKE can be used as a reliable measure in a stroke population.

2. Introduction

The incidence of stroke in Belgium is around 19.000 patients a year and will significantly rise as the aging population increases (Michiels et al., 2012). Patients with stroke often suffer from motor impairments, cognitive deficits and somatosensory impairments leading to an impact on performing activities of daily living and participation (Meyer et al., 2016). Somatosensory impairments occur in around 70% of patients after stroke (Carey & Matyas, 2011). These impairments can be present in different somatosensory modalities such as light touch, pressure, pinprick, sharp-blunt discrimination, proprioception and stereognosis. Proprioception and stereognosis are most frequently impaired, followed by tactile sensations in a stroke population (Connell, Lincoln, & Radford, 2008). Proprioception is critical to be able to generate and adapt movements, especially for fine motor function of the upper limb such as aiming, reaching and grasping. (Hasan, 1992; Sober & Sabes, 2003; Butler et al., 2004; Konczak et al., 2009). According to the literature, proprioception is an important predictor for recovery of sensorimotor function (Winward et al., 1999). To better understand the influence of proprioception on motor function and recovery, it is important to assess adequately. (Mrotek et al., 2017).

An all-encompassing definition of proprioception is given by Han, Waddington, Adamas, Anson, & Liu (2016), it is seen as an individual's ability to integrate the sensory information from proprioceptors to thereby determine body segment positions (position sense) and movements (kinaesthesia) in space. Sensory information about our body and environment is registered by receptors and send to the somatosensory cortex for processing and interpretation. These sensory receptors can be classified in three types: superficial, deep and combined cortical sensations (O'Sullivan, Schmitz, & Fulk, 2014). The exteroceptors receive stimuli from external environment via skin and subcutaneous tissue and are responsible for the superficial sensation (e.g. pain, temperature, light touch and pressure). Proprioceptors are responsible for deep sensations (e.g. vibration, position sense and kinaesthesia) and receive stimuli from muscles, ligaments, tendons and joints (O'Sullivan et al., 2014). This study will focus on proprioception.

Based on our previous master thesis - a review providing an overview of the outcome measurements of somatosensory disorders used in stroke patients - a small number of tests are used to evaluate proprioception. These tests are the Brief Kinaesthesia Test (Borstad & Nichols-Larsen, 2016), Thumb finding test (Smith, Akhtar, & Garraway, 1983), the Wrist Position Sense Test (Carey, Oke, & Matyas, 1996), the proprioception subtest of the Erasmus modification of the Nottingham Sensory Assessment (Stolk-Hornsveld, Crow, Hendriks, van der Baan, & Harmeling-van der Wel, 2006), Fugel-Meyer Assessment (Sanford, Moreland, Swanson, Stratford, & Gowland, 1993) and the Rivermead Assessment of Somatosensory Performance (Winward, Halligan, & Wade, 2002). Although these tests are simple and quick to administer, they are largely subjective, have lack standardized protocols and show poor interrater agreement (Lincoln, Jackson, & Adams, 1998; Winward et al., 1999; Borstad et al., 2016). Because their unprecise dichotomous or ordinal scales, the measurements can be used for screening patients and not to detect small functional improvements. (Hillier, Immink, & Thewlis, 2015). Therefore, new techniques for assessing proprioception are needed.

Recently, more quantitative assessment methods, by using technology, have be developed to measures proprioception in the upper limbs. The potential added value of a robotic tool is that they can provide repeatable sensory stimuli together with objective and quantitative measures of proprioception. Hillier et al. (2015) states that quantitative assessments of position sense could be a solution for the investigation of proprioception, as well as for diagnosis, prognosis and treatment planning for subjects with somatosensory deficits. Patients with strong proprioception deficits, have a worse prognosis for functional recovery (Feys, et al., 2000; Han, Law-Gibson, & Reding, 2002; Abela et al., 2012). Therefore, it is important to adjust the treatment based on a reliable and valid assessment of proprioception function in order to achieve the best possible rehabilitation outcomes. However, psychometric properties of robotic assessments, such as feasibility and reliability, are often either poorly evaluated and reported, or not reported at all in a stroke population (Hillier et al., 2015). The aim of this study was to report the feasibility and within and between session reliability of a rapid robotic assessment of finger proprioception using a passive gauge position matching task in stroke and healthy subjects. It is hypothesised that the MIKE is a feasible and reliable tool for measuring proprioception function in a stroke population.

3. Methods

3.1. Participants

Sixteen stroke participants were recruited in the Rehabilitation and MS centrum Overpelt and in the JESSA rehabilitation center St.-Ursula Herk-de-Stad. After drop-out, thirteen both in- and out patients were used for data analysis. In addition, thirteen healthy age-and gender-matched participants were recruited via relatives. Fig. 2 shows the flow chart of patient inclusion and drop-out. Inclusion criteria for the stroke group were a minimal age of eighteen, diagnosis of stroke (ischemic or haemorrhagic) and two weeks till twelve months post stroke. Exclusion criteria were a complete paralysis of both upper limbs, unable to detect any passive movement in hand and fingers, unable to place the hand in the robotic devices without any discomfort or pain, marked or severe intention tremor, marked or severe spasticity for finger and elbow flexors or shoulder adductors (Modified Ashworth scale >3), other medical conditions interfering with the hand function (peripheral nerve lesion, orthopaedic or rheumatoid impairment, pain and oedema) and severe cognitive or visual deficits interfering with testing and training (e.g. aphasia, severe neglect, …). All subjects gave written informed consent in accordance with the Declaration of Helsinki prior to participating in the experiment. The study was approved by the ethical committee of Hasselt University and the local committee of both participating rehabilitation centres.

3.2. Procedure

All outcome measures were performed in two test days for the healthy group (HG) and three days for the stroke group (SG) in order to minimize the influence of fatigue in the stroke patients. Each test session took average 30 minutes. The descriptive measures of the stroke group (SG) were conducted in the first day, the robotic assessments were done in the second and third day. The healthy group (HG) performed the descriptive measures together with the first robotic assessment on the first day.

The most affected hand was prioritized in the testing order to ensure that this data was less influenced by other factors such as fatigue. In the healthy group (HG) both hands were tested at random.

3.3. Descriptive measures

To describe the study sample following information was retrieved from the medical records: age, gender, duration of illness and type of stroke. In addition, following outcome measures were conducted to describe the overall disability level of the study population: Box and Block Test (BBT), Nine Hole Peg Test (NHPT), 25-feet Walking Test (25FWT), Manual Ability Measure-36 (MAM-36), Modified Ashworth Scale (MAS) and the Symbol Digit Modalities Test (SDMT). The Edinburgh Handedness Inventory (EHI) was used to assess the dominance of a person's right or left hand in ten everyday tasks like writing, brushing teeth etc. (Oldfield, 1971).

The Box and Block Test (BBT) was used to measure the manual dexterity (Mathiowetz, Volland, Kashman, & Weber, 1985). Participants were asked to move as many cubes from one side to the other, by using only the tested hand. The number of displaced blocks is a measure of the manual dexterity.

The Nine Hole Peg Test (NHPT) was used to measure the gross and fine motor skills of participants. Participants were asked to take nine pegs from a container, one by one, and place them into the holes on the board as quickly as possible, using the tested hand. Participants must then remove the pegs from the holes and replace them back into the container. The time needed to complete this task is registered (Mathiowetz et al., 1985).

25-feet Walking Test (25FWT) is a quantitative mobility and leg function performance test based on a timed 25-walk. Patients were asked to walk 25 feet as quick as possible. The time needed to complete the distance is registered. (Fischer, Jak, Knicker, Rudick, & Cutter, 2001).

Manual Ability Measure-36 (MAM-36) is a questionnaire on perceived ease or difficulty that a person may experience when performing unilateral and bilateral daily living activities (ADL) tasks. Participants were asked to rate 36 unilateral and bilateral ADL tasks using a four-point scale. The score of the different tasks were summed up and transformed using a Rasch-derived conversion table (Chen, Granger, Peimer, Moy, & Wald, 2005).

The Modified Ashworth Scale (MAS) measures the resistance during passive soft-tissue stretching and was used as a simple measure of spasticity. The therapist gives a score from zero to four depending on the resistance felt during passive movements (e.g. shoulder abduction, elbow-, wrist- and finger extension) (Ahmad Puzi, Sidek, Rosly, Daud, & Yusof, 2017).

The Symbol Digit Modalities Test (SDMT) was used to assess cognitive functioning (Smith, 1982). Participants were asked to match as many numbers to geometrical figures. The test can be administered written or orally. The amount of numbers that can be matched in 90 seconds is interpreted.

3.4. Primary outcome measures

3.4.1. Apparatus

The Motor Impairment and Kinaesthetic Evaluation (MIKE) is capable of providing reproducible passive flexions and extensions movements to the left and right metacarpophalangeal joint (MCP-joint) with direct-drive brushed DC motor (RE65, Maxon Motor, Sachseln, Switzerland). The angular position is measured with a high-resolution optical encoder fixed to the motor shaft (RI58, 1 million counts/rev, Gurley Precision Instruments, Troy, NY, USA) allowing for a good position and velocity resolution at high sampling rates during fast finger movements. Appendix 1 shows the instruction of the MIKE.

3.4.2. Robot procedure

Subjects were seated in front of the device. The hand and index finger were first strapped to the 3D printed handle in a pistol grip position after ensuring an optimal alignment of the wrist joint. Afterwards, the assessor checked if the movement axis corresponds well to the axis of the MCP-joint, and if the movement felt comfortable. After positioning the subject, the tablet is placed on the frame above the tested hand to prevent participants from seeing their hand. A step was placed under the device in order to make an inclination of the tablet for a better view (Fig.1). In every trial, the robot moved the index finger from the neutral position (0° MCP flexion, 30° wrist flexion) to a new position. Once subjects indicated the reported angle on the

tablet, the device moved back to the neutral position from where the next trial would start. Subjects had no time limit and performed each trial as accurate as possible. When patients were not able to indicate the place on the tablet, assessors would do it for them based on the instruction of the patient. Afterwards the other hand was tested. In one total session, three sets of 21 trials of each hand were offered in a randomized order from 10 degrees to 30 degrees. Prior to the actual testing, five practice trials were offered to get used to the device. Between each set, patients were given a break to minimize bias due to concentration loss.

3.4.3. Outcome measures extracted from MIKE

To compare to other studies in the literature, four proprioceptive outcome measures were reported, namely the constant error (CE = average error), absolute error (AE = average absolute error), variable error (VE = standard deviation of errors) and total variability (E = root mean square of errors) in degrees. The error is calculated by comparing the difference in degrees of the real angle presented by the robot and the reported angle indicated by the participants. A positive CE represents an overestimation of the MCP-flexion angle, whereas a negative CE represents an underestimation. The CE, AE, and E follow the standard definitions according to Schmidt and Lee (2011) and VE was implemented according to Rinderknecht et al. (2016). The VE represents the variability, implemented as the standard deviation, in the error distribution between the trials. The required administration time of the assessment is also registered.

3.4.4. Feasibility

The usability of the device was measured by the System Usability Scale (SUS). Participants are asked to score ten items with one of five responses that rage from ‘strongly agree’ to ‘strongly disagree’ (Brooke, 1996). For odd items, the score is the user's response minus one, for even-numbered items, the score is five minus the user’s response. The sum of these scores are multiplied by 2.5, this gives a score with a range from zero till 100. The number of patients who were not able to actively indicate the gauge on the tablet and the number dropping out of the study were registered.

3.5. Secondary outcome measures

3.5.1. Clinical measures

Light touch was assessed by the Semmes-Weinstein Monofilaments (SWM) on the palmar site of the DIP of the thumb and index finger. Five monofilaments are each placed on the skin with increasing force until bending. The filament is held in place for one till 1.5 seconds, and then removed. This is repeated three times for each area. Each time a patient was able to feel a filament, a positive score was assigned (Semmes, Weinstein, Ghent & Teuber, 1960).

Vibration sense was tested by Rydel Seiffer Tuning fork (RSTf) on dorsal side of the ulnar styloid and DIP-joint of the index finger. The position of the triangle, when the patient is no longer perceiving vibration, is recorded on a scale from two to eight (Panosyan, Mountain, Reilly, Shy, & Herrmann, 2016).

Light touch, pinprick, pressure, sharp-blunt discrimination and proprioception of the upper limb was assessed by the Erasmus Modification of the Nottingham Sensory Assessment (EmNSA). The EmNSA uses three categorical scores (absent, impaired and normal). (Stolk-Hornsveld et al., 2006)

3.6. Data analysis

All statistical analyses were performed in SPSS 25.0 (Statistical Package for the Social Science). The Shapiro-Wilk test was used to check normality. Descriptive statistics are reported as mean ± standard deviation for normal distributed data, and by quartiles range if no normality was seen [Q1-Q3]. Differences between the patient and healthy group were tested by using paired t-tests, respectively Wilcoxon signed-rank test for not normally distributed data. Significance levels were set to $p = 0.05$.

3.6.1. Reliability

Reliability is the degree of consistency between repeated measurements. Reliability was measured by calculating the Intraclass Correlation Coefficient (ICC) values of the errors between the real and reported angle (two-way layout with random effects for absolute

agreement) (Shrout & Fleiss, 1979). Values less than 0.50, between 0.50 and 0.75, between 0.75 and 0.90, and greater than 0.90 are respectively indicative of poor, moderate, good, and excellent reliability according to Terry and Mae (2016).

The standard error of measurement (SEM) were calculated according to Portney and Watkins (2009). SEM (°) represents the estimated standard deviation of errors between the reported angle versus the real angle (SEM= SD$\sqrt{1-ICC}$). The SEM characterises the average measurement variability. As the sample standard deviation (SD) is an indication of the variability of the measures, the SEM is an estimate of the variability comparing the measures.

3.6.2. Within session reliability

Statistical analysis of the within session reliability was done by pooling the three sets (each containing 21 trials) of the two sessions of the same day and this for the two days separately. Then, the ICC value and SEM were calculated for the E, CE, AE and VE within the same sessions.

3.6.3. Between session reliability

Statistical analysis of the between session reliability was done by comparing the two different sessions. Set 1, 2 and 3 of session 1 were respectively compared to set 1, 2 and 3 of session 2. ICC value and SEM were calculated based on the differences of the E, CE, AE, VE between the sessions. In addition, between session reliability for the secondary outcomes measures was analysed based on the agreement of the scores between session 1 and 2.

4. Results

4.1. Participants

Sixteen stroke participants were recruited. After drop-out, thirteen participants (7 male and 6 female, mean age 67.3 $\pm$ 10.5) were used for the data analysis of the stroke group with a mean disease duration of 84.5 days and thirteen healthy subjects (7 male and 6 female, mean age 66.5 $\pm$ 10.5) were included in the healthy group. Fig. 2 shows the flow chart of patient inclusion and drop-out. The stroke group scored significantly worse for both hands on the BBT (< 0.001), 9HPT (< 0.002), T25FWT (< 0.001), MAM-36 (< 0.001), MAS and SDMT (< 0.001) than the healthy group. Three patients were not able to perform the 9HPT with their most affected hand because of motor deficits and two out of these three patients could not perform the T25FWT. Table 1 shows the baseline characteristics of both groups.

4.2. Feasibility

Two patients dropped out of the study because of a lack of motivation and one became unwell during the robotic assessment. The fact he became unwell was due to his medical condition and not because of the assessment. Six patients were assisted by the assessor because they were not able to indicate on the tablet due to severe motor deficits. Five out thirteen patients could not complete all sets for both hands of one session due to fatigue. E.g. one patient could not perform set three of one particular session of the less affected hand. Another patient could not perform set three of the most affected hand and all sets of the less affected hand.

The mean score of the System Usability Scale of the patient group is 75.8 ± 4.25 (95% CI= 66.5-85.0). People mostly disagreed with the question of they would like to use the system frequently. They also felt they need support of a technical person to be able to use this system. However, patients agreed the system was easy to use and not too complex.

Even though, some participants stated that one complete session of three sets was exhausting and monotonous. The administration time, an additional parameter of the study, of the first session (19.25 minutes ± 4.43) was significantly ($p < .001$) higher in the stroke group then the

second one (16.50 ± 3.74). This data is calculated based on eight out of thirteen patients. The administration time was not registered in the remaining patients.

4.3. Outcome measures extracted from MIKE

The mean score of the most affected hand in the stroke patients on the proprioceptive outcome measures of all sessions resulted in 18.91°± 8.97 for the E, -3.71°± 18.30 for CE, 17.16°± 8.80 for AE, 9.14°± 4.60 for VE. The data of the less affected hand resulted in 11.99°± 8.31 for the E, 2.51°± 12.40 for CE, 10.49°± 8.27 for AE, 7.13°± 2.46 for VE. Fig. 3 and 4 shows the scatter plots of the data extracted from MIKE for the stroke group. Fig. 5 and 6 shows the scatter plots for the healthy group.

4.4. Reliability

4.4.1. Within session reliability

For the stroke patients a moderate to excellent agreement was seen for the most affected hand with ICC values for the four different parameters E (0.84-0.94), CE (0.94-0.98), AE (0.83-0.96) and VE (0.68-0.69). High to excellent agreement was seen for the less affected hand with ICC values for the E (0.96-0.98), CE (0.93-0.96), AE (0.96-0.99) and VE (0.83-0.88). There was moderate to excellent agreement for both hands of the healthy group with ICC values of the E (0.90-0.95), CE (0.69-0.95), AE (0.88-0.96) and VE (0.62-0.88). The ICC values of the reliability of the healthy group were overall lower than the values of the stroke group. ICC values of the most affected hand in stroke patients were lower than the less affected. Table 2 shows the within session reliability for both groups.

The within session SEM of the most affected hand was situated between 1.78° and 4.23° for all outcome measures. The SEM was lower for the less affected hand and situated between 0.89° and 3.64°. The SEM of the healthy group situated between 0.34° and 1.80°. Table 3 shows the mean, standard deviation and SEM within session.

4.4.2. Between session reliability

There was poor to excellent agreement of the most affected hand between both sessions with ICC values for the E (0.59-0.89), CE (0.74-0.93), AE (0.55-0.90) and VE (0.32-0.86). High to excellent agreement was seen for the less affected hand with ICC values for the E (0.84-0.92), CE (0.76-0.85), AE (0.82-0.94) and VE (0.79-0.90). ICC values of the most affected hand were lower than the less affected. There was poor to excellent agreement for both hands of the healthy group with ICC values of the E (0.38-0.89), CE (0.32-0.96), AE (0.38-0.91) and VE (0.32-0.52). Overall, the ICC's of the within session reliability are higher, compared with the ICC's of the between session reliability. Table 4 shows the between session reliability of MIKE.

The between session SEM of the most affected hand was situated between 1.38° and 8.50°. For the less affected hand, SEM was lower and situated between 0.94° and 6.00°. The SEM of the healthy group was situated between 0.60° and 2.51°. Table 5 shows the mean, standard deviation and SEM between session.

4.5. Secondary outcomes

4.5.1. between session reliability

For both hands in the stroke group, excellent agreement (ICC= 0.91-0.95) was found for the SWM, a poor to high agreement (ICC= 0.38-0.80) for the RSTf and high to excellent agreement (ICC= 0.77-1.00) for the EmNSA. Table 7 shows the between session reliability for the secondary outcomes for the stroke. The healthy group had all maximum scores in both hands on the RSTf and EmNSA. The ICC value of the SWM for the healthy group in both hands ranged from 0.92 to 1 for both dominant and non-dominant hand.

5. Discussion

In this study we evaluated an automated gauge position matching task using a robotic setup to assess finger (index) proprioception with regards to feasibility and reliability. Such assessment can provide the same repeatable position of the finger, together with objective and quantitative estimates of proprioception. Quantitative assessments of position sense could be important for the investigation of proprioception, prognosis and treatment planning for patients who suffered from stroke.

5.1. Feasibility

The mean score of the System Usability Scale of the stroke group is 75.8 (95% CI= 66.5-85.0). Scores higher than 68 are considered as above average (Brooke, 1995). This score demonstrates that MIKE is a feasible device in a stroke population. 80% of stroke patients suffer from motor deficits (Rathore, Hinn, Cooper, Tyroler, & Rosamond, 2002), accordingly an advantage of MIKE is that no motor function is required to perform the test. When a patient is not able to indicate the angle on the tablet, the assessor would do it. Patients were asked to say “stop” when they felt the positions matched. Stroke patients often have slower reaction time and could have had a delay on saying “stop” when the assessor is slowly moving the gauge (Miscio, Pisano, Del Conte, Colombo, & Schieppati, 2006). This could have affected the results.

Rinderknecht et al. (2016) concluded that a short assessment with 21 trials already provided a representative estimation of the subject’s proprioceptive finger function and that there is no major information and precision loss compared to a longer assessment. This is essential, as a short assessment duration is required for application in a clinical setting. However, in this study, the assessment consisted of three sets of 21 trials. Between each set patients were given time to minimize loss of concentration. Even though these efforts were made, some patients stated that one complete session of three sets was exhausting and monotonous. This could have affected the results, as there was a selective loss to follow up; two patients dropped out of the study because of a lack of motivation.

Patients with stroke often present with fatigue and concentration problems while performing longer tasks that require attention. The prevalence of fatigue in a stroke population ranges from 29% to 77% (Acciarresi, Bogousslavsky, & Paciaroni, 2014). This has led that five out thirteen patients could not complete all sets for both hands of one session due to fatigue.

In this study all assessors were adequately trained for one hour to place the subject in a correct and comfortable position in the device (e.g. there was ensured that the robot only moved in the MCP-joint). There should be a similar training session in future studies of MIKE to minimize assessor bias.

5.2. Reliability

5.2.1. Within session reliability

The ICC values calculated for the within session reliability in both groups were moderate to excellent all outcome measures. Based on these results MIKE is a reliable assessment for proprioceptive function of the index finger in a stroke and healthy population within one session. The ICC values of the within session reliability of the stroke group were overall higher than the values of the healthy group, however this was just a slight difference. An important factor to take into account while interpreting these ICC values is the inter-subject variability. The stroke group shows more inter-subject variability compared to the control group (fig. 2, 3, 4 & 5). A possible explanation of higher ICC values for the stroke group could be explained by the heterogeneity of this group. In a heterogenous group with larger inter-subject variability, the same intra-subject variance will represent proportionately less of the total variance, which leads to an increase of the ICC-values (Michell, 1979; Keating & Matyas, 1998).

Patients scored significantly ($p = .017$) worse for the affected hand on set 1 compared to set 2 in the first session. This could be due to learning effect. However, there were no other differences when comparing set 1 to 2, 2 to 3 and 1 to 3.

5.2.2. Between session reliability

Two sessions of robotic measurements on consecutive days were implemented in this study. Longer intervals are advised to prevent confounding factors, such as recall bias, but still short enough so patients do not improve or regress on the measured construct (Streiner & Norman, 2008).

The ICC values of the most affected hand had good to excellent between session reliability for the CE, moderate to good for AE as well as for E, and poor to good for VE. The high ICC values for CE, could be explained that CE is an average and compensates for extreme values. Rinderknecht et al. (2016) states that the AE and the E may not suffer from high intra-subject variability in a healthy population and thus could be used as outcome measures for proprioception. Based on the results of our study, the E, CE and AE can be used as a reliable outcome measure in a stroke population. In figures 2, 3, 4 & 5, the VE shows a large intra-subject variability compared to the inter-subject variability. Thus, it is not recommended to use the VE as a meaningful outcome measure for subject performance consistency in a stroke population cause of its poor reliability and large intra-subject variability. However, caution is advised because the sample size is rather small (26 subjects). It has been recommended that the sample size should be at least 30 for interpreting the within session reliability (Hopkins, 2000). Further research of a larger group of patients is necessary to fully establish the reliability of MIKE in a stroke population.

Wycherley, Helliwell, & Bird (2005) also investigated the between session reliability of a proprioceptive assessment at the level of the MCP joint in healthy subjects. This study made also use of a matchings-task paradigm, however the finger position was manually presented and measured by an assessor based on a protractor. The ICC values for the average error (comparable with the CE in this study) ranged from 0.67 to 0.98 and are similar to our study.

Reliability of robotic assessment of proprioceptive function of the upper limb joints has been measured and reported by only a few previous studies in a stroke population. One study used a robot to assess proprioception and motor performance of the whole arm (Simo, Botzer, Ghez, & Scheidt, 2014). However, this study did not use ICC or SEM values and can therefore

not be used to compare. Semrau, Herter, Scott, & Dukelow (2017) used an exoskeleton to measure proprioception of the elbow. Other parameters for measuring the CE were used in this study to calculate the between session reliability. Therefore, these ICC values cannot be compared to our study.

The ICC values of the between session reliability are overall lower than the values for the within reliability, also the values of the most affected hand were lower compared to the less affected hand. Both findings could be due to external factors, such as general feeling or mood. The amount of therapy during day before the assessment could also be a contributing factor because patients continued with their rehabilitation concurrent with this study.

SEM ranges from 0.94° to 8.50° and was lower than the SD for every measure. An improvement of proprioceptive function after rehabilitation can thus be stated when the difference in the patients score is higher than the SEM. In this study the percentage SEM was not calculated because the sample size was too small. Future studies should calculate the percentage SEM to give a better comparison with other outcome measures. Further research is also needed to calculate the Minimal Clinically Important Difference (MCID) in order to establish the responsiveness of MIKE.

5.2.3. Secondary outcome measures

The secondary outcome measures (e.g. EmNSA) in this study tend to have poor between session reliability as they lack standardized protocols and suffer from large variability due to manual administration (Winward et al, 1999). This could have led to a slight difference in assessing between different sessions. To minimize this influence, there was an instruction booklet for each assessment, a training session was given to each assessor and both sessions of the same patient were executed by the same assessor in this study. Excellent agreement was found for the SWM, a poor to high agreement for the RSTf and high to excellent agreement for the EmNSA.

5.3. Methodology aspects

When patients have a loss of a sensory modality, another preserved modality is generally used to supply equivalent sensory signals (Bach-y-Rita, & Kercel, 2003). Patients often compensate for proprioceptive loss in daily life. Effective compensatory strategies, such as imagery-based movement, were seen in a stroke population with proprioceptive deficits (Stevens, Cole, & Vishton, 2011). There could also have been some compensations for proprioceptive deficits in this study based on our clinical experience with the MIKE. Patients could hear the robot moving to the desired position. This could have led to better scores for patients with more severe proprioceptive deficits. However, this compensation can easily be avoided in future studies by giving the participants headphones.

Subjects could have also relied on the time the robot placed the index finger in the real angle. They could make an estimation of the angle based on their moving sense and thus not relying on proprioceptive ability. It is therefore debatable if MIKE is a measure of kinaesthesia and not proprioception. Further research of the MIKE is required to establish the validity.

Another issue was the influence of the pressure applied to the finger in the handle. If the tape applied more pressure to the participants finger they could have more sensory feedback. Patients sometimes asked to wrap the tape harder around their finger. The difference in the applied pressure could have affect the results, especially for patients who relied on this. Batavia, Gianutsos, Ling, & Nelson (1999) showed that circumferential wrist pressure improved accuracy in joint position sense, particularly in elderly individuals with age-related deficits of proprioception.

A last possible compensation for the lack of proprioceptive function is the vibration stimuli given by the finger module. Both proprioception and vibration sense share similar pathways through the spinal cord and brainstem, although having different receptors mediating these sensory functions and terminating upon different thalamic and cerebral cortical neurons. Some neurological disorders like stroke can affect one of these sensory functions while partially or completely sparing the other one (Gilman, 2002). The vibration of the finger

module in our study could have given another feedback mechanism for patients with intact vibration and impaired proprioception sense and therefore could have influenced the results.

Aman, Elangovan, Yeh, & Konczak (2014) states the role of proprioception of the hand is essential for modifying hand/finger position, grip strength and placing during grasping tasks. The movements evaluated with MIKE are though isolated, passive and not functional and therefore one could argue that assessments of the whole-limb position sense give a better representation of proprioception in daily life activities (Dukelow et al., 2010). However whole-limb assessments require extensive setups compared to one degree of freedom for single joint assessments (Hillier et al., 2015). Therefore, the MIKE is easier to introduce in a clinical setting. Moreover, the similarity between different body areas for proprioceptive function is high, suggesting it is not necessary to evaluate multiple joints (Connell et al., 2008).

6. Conclusion

MIKE is a feasible device to measure proprioception in a stroke and healthy population. There was good to excellent between and within session reliability found for both hands in the stroke group for the E, CE and AE. Therefore, MIKE can be used as a reliable measure of MCP-joint proprioception in a stroke population. Caution is advised when interpreting these results, because further research on a larger sample size is required to establish the reliability.

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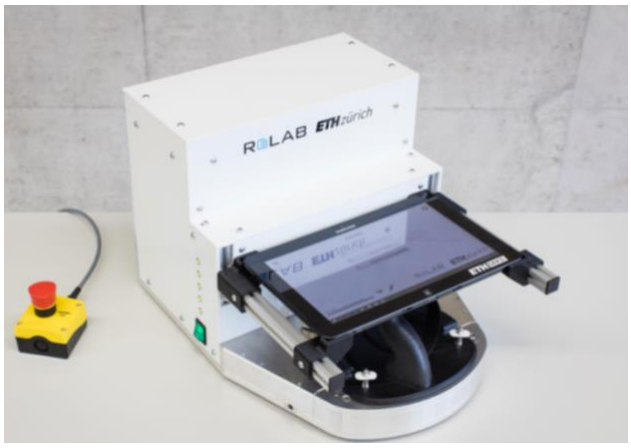
APPENDIX 1

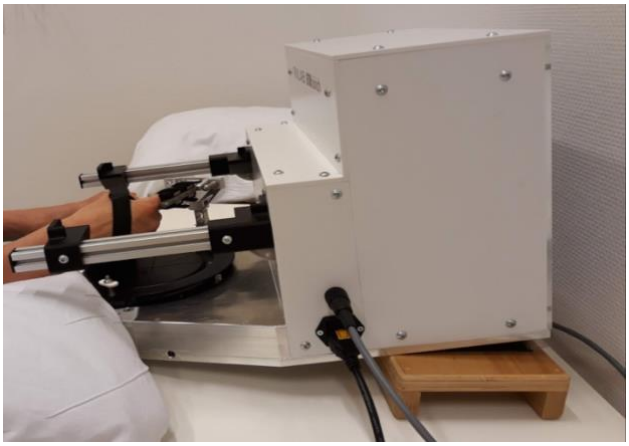
Instruction MIKE (Dutch)

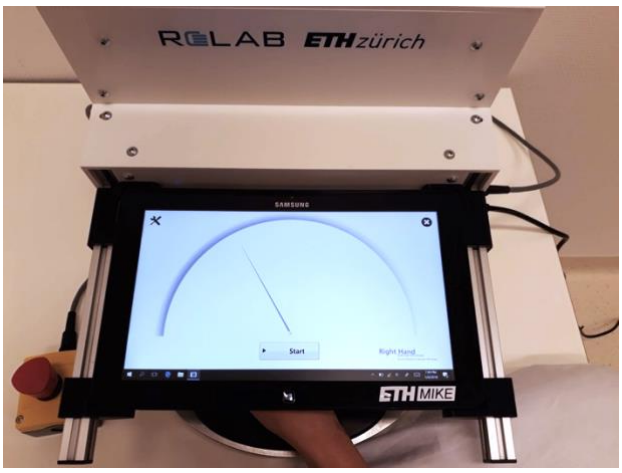
Als de deelnemer zich in de startpositie plaatsvindt, worden de volgende instructies gegeven:

Bekijk de beginpositie van uw wijsvinger, deze zal overeenkomen met de lijn aangeduid op het platform.

- Zorg dat de elleboog ondersteund is.
- Zit recht voor de robot en zorg ervoor dat u recht op de tablet kijkt.
- Zit u/de hand comfortabel?
- Plaats de tablet op de robot.
- U kan nu zien dat de vinger overeenkomt met de grijze naald.
- Zodra u op start druk, gaat de robot uw vinger bewegen naar de handpalm. Zorg ervoor dat u de vinger ontspant en niet actief gaat meebewegen.
- Het is de bedoeling dat u de naald in dezelfde positie als de wijsvinger gaat plaatsen met de pen. Probeer uw vinger zo goed mogelijk te overeenkomen met de blauwe lijn. Je kan steeds wijzigingen aanbrengen, er is geen tijdslimiet. Het belangrijk om dit zo goed mogelijk te doen, en niet zo snel mogelijk.
- Druk op valideren zodra u denkt dat de naald in de juiste positie staat.
- Na het valideren gaat de vinger terug naar de startpositie.
- U krijgt eerst de mogelijkheid om enkele keren te proberen om gewoon te worden aan de robot.
- Wanneer er daarna geen problemen of vragen meer zijn, gaan we over naar de testing zelf.
- Wanneer u pijn heeft, of een noodgeval druk op de rode noodknop.







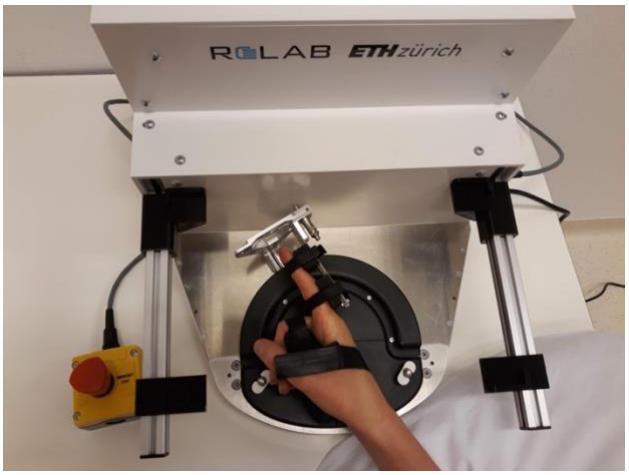


Figure 1: Apparatus MIKE

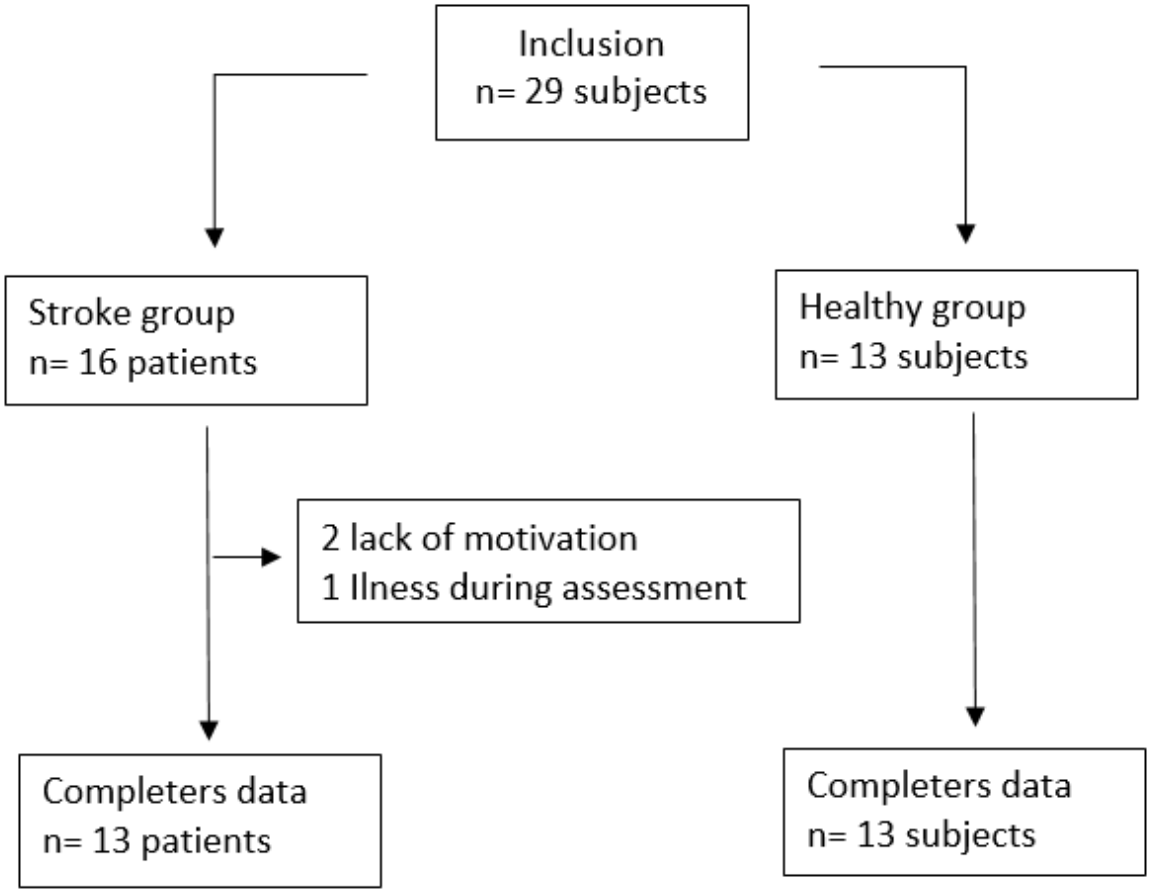


Figure 2: Flow chart of patient inclusion and drop-out

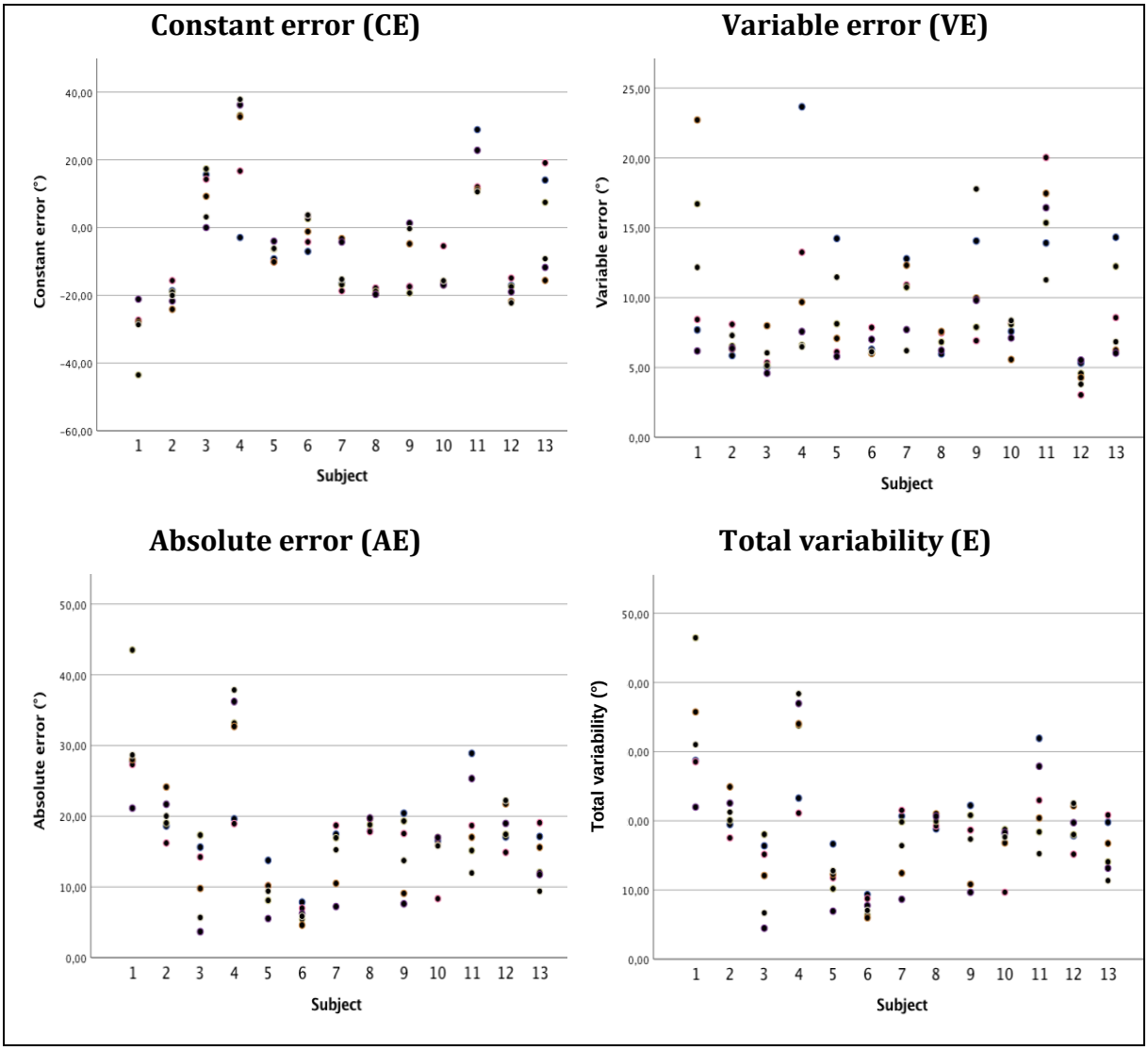


Figure 3: Scatter plots illustrating the intra- and inter-subject variability for the outcome measures constant error (CE), absolute error (AE), variable error (VE) and total variability (E) in the most affected hand of the stroke group. Each measurement is represented by one circle.

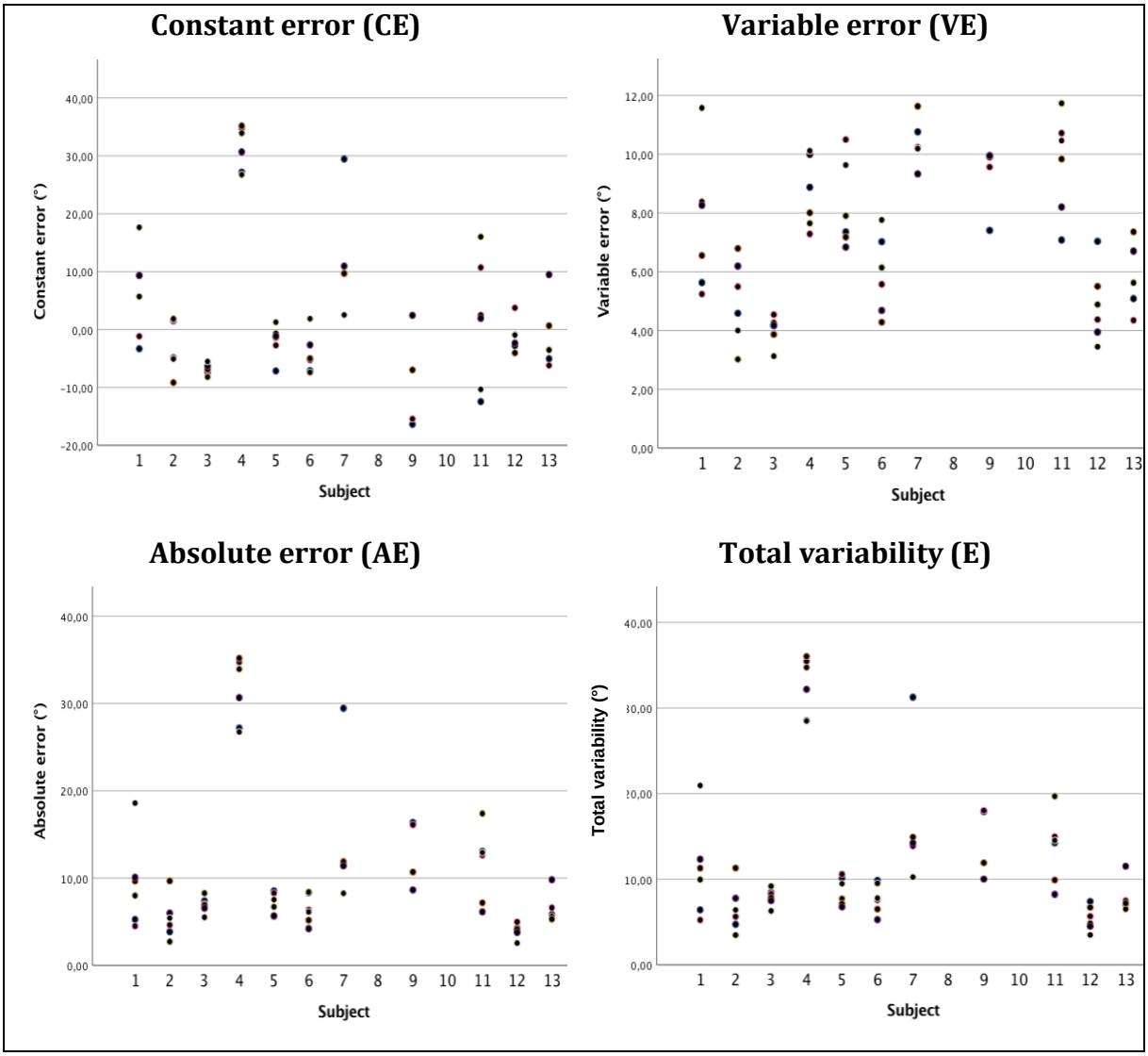


Figure 4: Scatter plots illustrating the intra- and inter-subject variability for the outcome measures constant error (CE), absolute error (AE), variable error (VE) and total variability (E) in the less affected hand of the stroke group. Each measurement is represented by one circle.

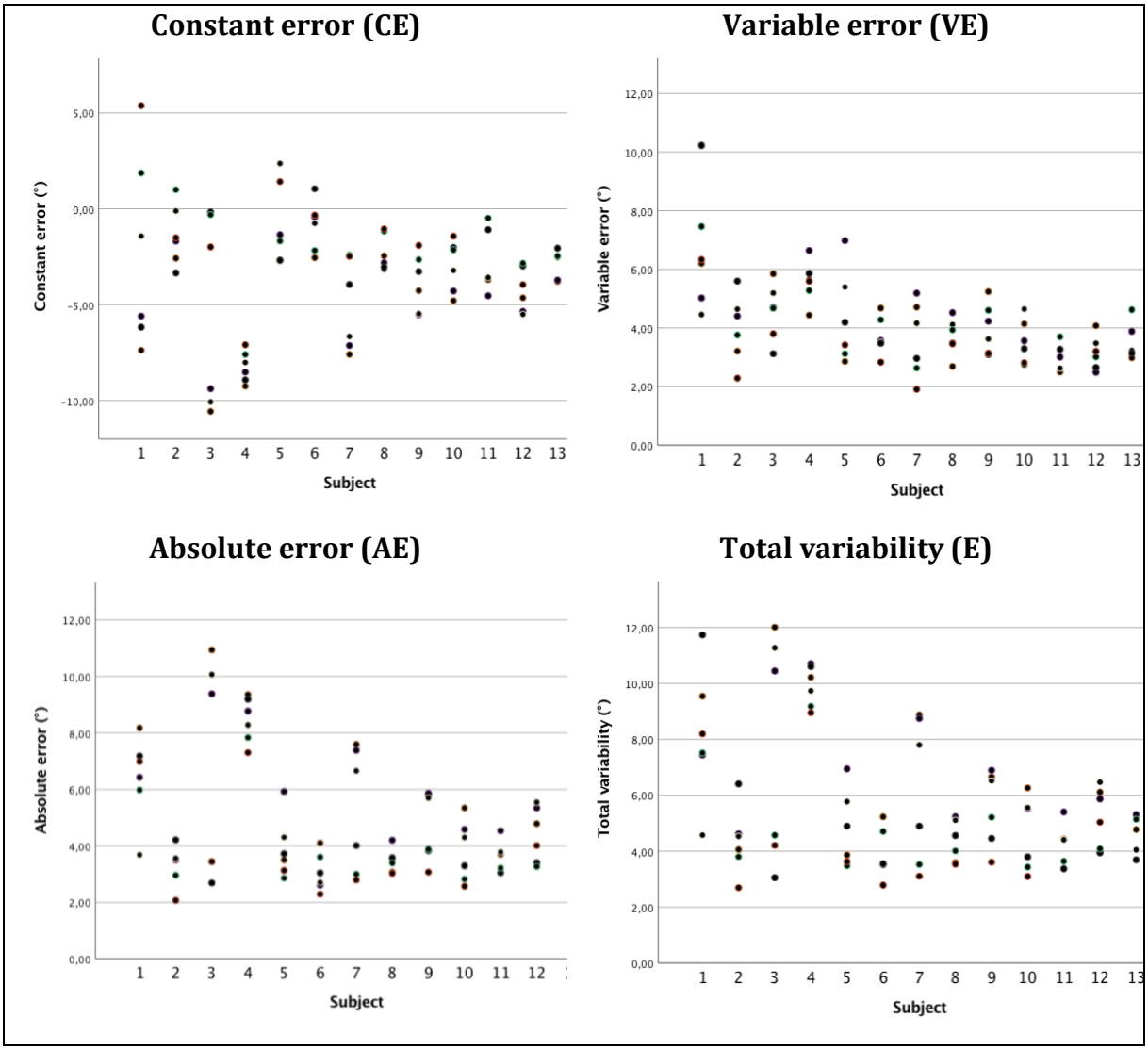


Figure 5: Scatter plots illustrating the intra- and inter-subject variability for the outcome measures constant error (CE), absolute error (AE), variable error (VE) and total variability (E) in the dominant hand of the healthy group. Each measurement is represented by one circle.

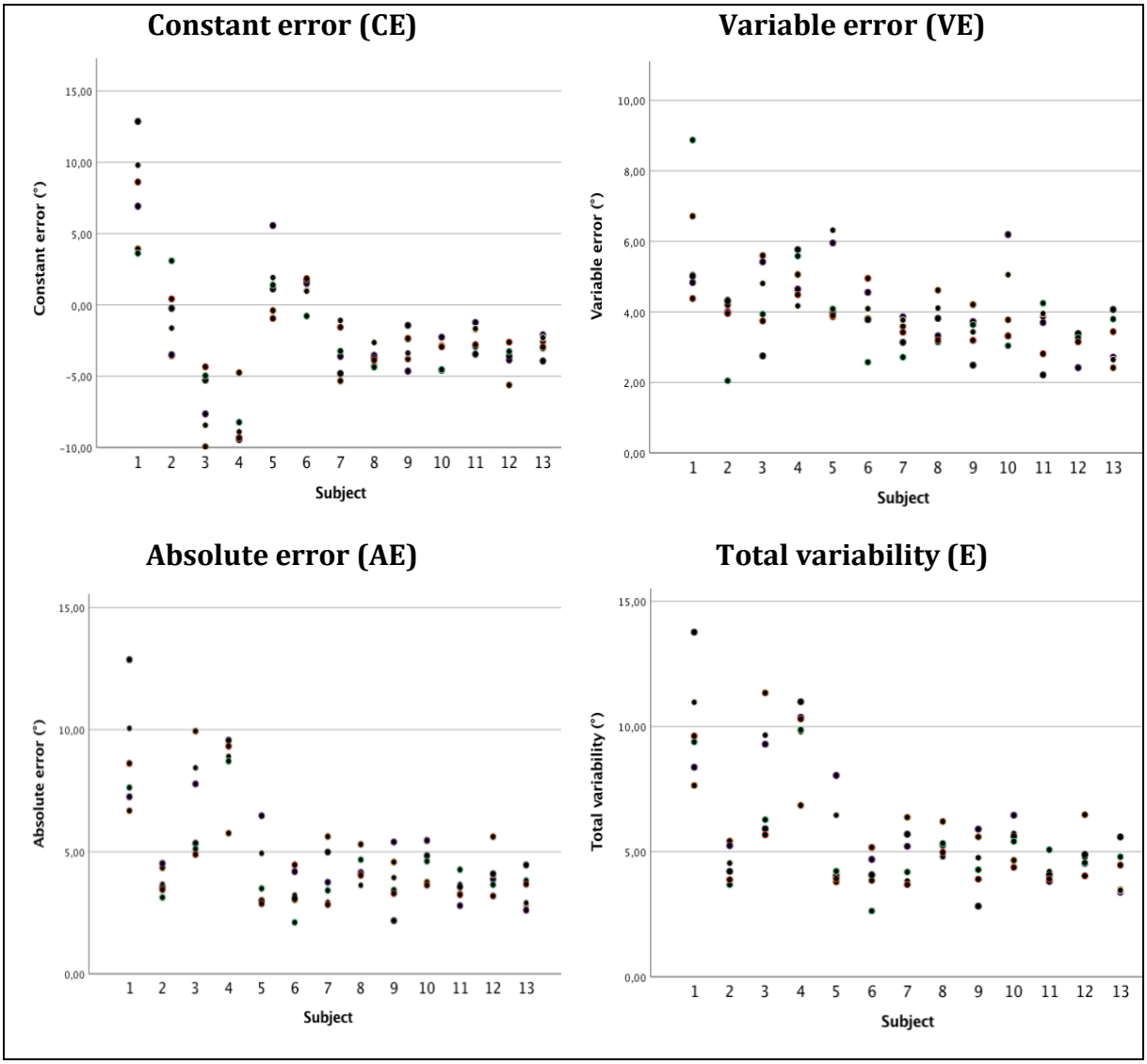


Figure 6: Scatter plots illustrating the intra- and inter-subject variability for the outcome measures constant error (CE), absolute error (AE), variable error (VE) and total variability (E) in the non-dominant hand of the healthy group. Each measurement is represented by one circle.

Table 1: Participants characteristics and descriptive measures

	Stroke group	Healthy group	P-value
Number	13	13	
Age, mean years (SD)	67.3 (10.5)	66.5 (10.5)	0.863
Duration of disease, mean days [Q1-Q3]	84.5 [40,5-119,5]	/	
Sex (male/female)	7/ 6	7/6	1
Lesion side (right left/bilateral)	7/ 4 /2	/	
Type of stroke (Ischemic/haemorrhagic)	11/2	/	
Hand dominance EHI (right/left/ambidextrous)	10/3/0	11/2/0	
BBT			
most affected / right, mean (SD)	18.5 (13.9)	54.1 (5.9)	<0.001
less affected / left, mean (SD)	30.5 (9.0)	53.1 (6.6)	<0.001
9HPT			
most affected / right, mean (SD)	41.2 (15.0)	20.6 (2.5)	<0,001
less affected / left, mean (SD)	28.8 (6.9)	21.1 (2.7)	0.002
25FWT (sec), mean [Q1-Q3]	10.9 [6.2-10.7]	3.5[2.5-4.9]	<0.001
MAM-36, mean [Q1-Q3]	58,4 [50.3-64.8]	100 [100-100]	<0.001
MAS, mean [Q1-Q3]	1.00 [0-2]	/	
SDMT, mean (SD)	26.2 (11.9)	46,08 (4,9)	<0.001

EHI; Edinburgh Handedness Inventory, NHPT; Nine Hole Peg Test, BBT; Box and Block Test, 25FWT; 25-feet Walking Test, MAM-36; Manual Ability Measure-36, SDMT; Symbol Digit Modalities Test, MAS; Modified Ashworth Scale, SD; standard deviation, CI; confidence interval, Q1; percentile 25, Q3; percentile 75

Table 2: Within session reliability of MIKE: ICC-values and 95% confidence Interval for both groups

	session 1 **ICC [95% CI]** / ICC [95% CI]	session 2 **ICC [95% CI]** / ICC [95% CI]
E		
Most affected / dominant	**0.84 [0.60-0.95]** / 0.94 [0.84-0.98]	**0.94 [0.85-0.98]** / 0.91 [0.75-0.98]
Less affected / non-dominant	**0.98 [0.95-1.00]** / 0.90 [0.73-0.97]	**0.96 [0.88-0.99]** / 0.95 [0.87-0.98]
CE		
Most affected / dominant	**0.94 [0.85-0.98]** / 0.93 [0.80-0.98]	**0.98 [0.96-1.00]** / 0.69 [0.19-0.91]
Less affected / non-dominant	**0.93 [0.76-0.98]** / 0.95 [0.87-0.98]	**0.96 [0.89-0.99]** / 0.95 [0.87-0.98]
AE		
Most affected / dominant	**0.83 [0.59- 0.94]** / 0.95 [0.86-0.98]	**0.96 [0.88-0.99]** / 0.96 [0.87-0.99]
Less affected / non-dominant	**0.99 [0.95-1.00]** / 0.88 [0.70-0.96]	**0.96 [0.89-0.99]** / 0.94 [0.84-0.98]
VE		
Most affected / dominant	**0.69 [0.22-0.90]** / 0.62 [0.04-0.88]	**0.68 [0.17-0.90]** / 0.88 [0.67-0.97]
Less affected / non-dominant	**0.83 [0.45-0.96]** / 0.81 [0.51-0.94]	**0.88 [0.63-0.97]** / 0.64 [0.05-0.88]

ICC; Interclass Correlation coefficient, CI; Confidence interval, E; Total variability, CE; Constant Error, AE; Absolute Error, VE; Variable Error

Table 3: Mean, standard deviation, Standard Error of Measurement within session for both groups

	SEM [°] within session			
	session 1		session 2	
	Mean ± SD / Mean ± SD	SEM	**Mean ± SD** / Mean ± SD	SEM
E				
Most affected / dominant	**19.45 ± 7.41** / 6.51 ± 2.41	**2,96°** / 0.59°	**17.94 ± 8.99** / 4.87 ± 2.22	**2.20°** / 0.67°
Less affected / non-dominant	**12.60 ± 8.98** / 6.10 ± 2.22	**1.27°** / 0.70°	**11.62 ± 7.93** / 5.77± 2.48	**1.59°** / 0.55°
CE				
Most affected / dominant	**-6.06 ± 17.28** / -4.5 ± 3.02	**4.23°** / 0.80°	**-5.48 ± 17.13** / -2.07 ± 2.64	**2.42°** / 1.47°
Less affected / non-dominant	**1.99 ± 13.74** / -2.38 ± 4.28	**3.64°** / 0.96°	**3.23 ± 11.53** / -1.93 ± 4.33	**2.31°** / 0.97°
AE				
Most affected / dominant	**17.69 ± 7.22** / 5.49 ± 2.26	**2.97°** / 0.51°	**16.23 ± 8.89** / 3.92 ± 1.68	**1.78°** / 0.34°
Less affected / non-dominant	**11.23 ± 9.09** / 5.16 ± 2.08	**0.91°** / 0.72°	**9.72 ± 8.31** / 4.71 ± 2.35	**1.66°** / 0.58°
VE				
Most affected / dominant	**9.44 ± 4.56** / 4.31 ± 1.14	**2.54°** / 0.70°	**8.51 ± 4.13** / 3.97 ± 1.60	**2.34°** / 0.55°
Less affected / non-dominant	**6.90 ± 2.36** / 4.30 ± 1.02	**0.97°** / 0.44°	**7.31 ± 2.57** / 3.80 ± 3.02	**0.89°** / 1.80°

SD; Standard deviation, SEM; Standard Error of Measurements, E; Total variability, CE; Constant Error, AE; Absolute Error, VE; Variable Error

Table 4: Between session reliability of MIKE: ICC-values and 95% confidence interval for both groups

	ICC between session 1 & 2		
	session 1 set1 vs. session 2 set 1	Session1 set 2 vs. session 2 set 2	Session 1 set 3 vs. session 2 set 3
	ICC [95% CI] / ICC [95% CI]	**ICC [95% CI]** / ICC [95% CI]	**ICC [95% CI]** / ICC [95% CI]
E			
Most affected / dominant	**0.72 [0.10-0.92]** / 0.55 [-0.31 -0.86]	**0.59 [-0.44-0.88]** / 0.51 [0.26-0.84]	**0.89 [0.65-0.97]** / 0.38 [-0.48-0.81]
Less affected / non-dominant	**0.84 [0.40-0.96]** / 0.57 [-0.53-0.87]	**0.92 [0.73-0.98]** / 0.81 [0.40-0.94]	**0.92 [0.58-0.98]** / 0.89 [0.63-0.97]
CE			
Most affected / dominant	**0.74 [0.12-0.92]** / 0.74 [-0.31-0.82]	**0.78 [0.26-0.93]** / 0.32 [-0.36-0.74]	**0.93 [0.77-0.98]** / 0.67 [-0.11-0.91]
Less affected / non-dominant	**0.85 [0.45-0.96]** / 0.83 [-0.46-0.95]	**0.84 [0.42-0.96]** / 0.86 [0.53-0.96]	**0.76 [-0.27-0.95]** / 0.96 [0.87-0.99]
AE			
Most affected / dominant	**0.68 [-0.05-0.95]** / 0.55 [-0.21-0.85]	**0.55 [-0.60-0.87]** / 0.46 [-0.29-0.82]	**0.90 [0.65-0.97]** / 0.38 [-0.57-0.89]
Less affected / non-dominant	**0.82 [0.36-0.95]** / 0.61 [-0.39-0.88]	**0.94 [0.78-0.98]** / 0.82 [-0.41-0.94]	**0.92 [0.57-0.98]** / 0.91 [-0.70-0.97]
VE			
Most affected / dominant	**0.32 [-1.42-0.80]** / 0.52 [-0.74-0.86]	**0.86 [0.51-0.96]** / 0.37 [-1.13-0.81]	**0.60 [-0.50-0.89]** / 0.42 [-0.45-0.82]
Less affected / non-dominant	**0.79 [0.25-0.94]** / 0.47 [-0.49-0.83]	**0.79 [0.17-0.94]** / 0.32 [-1.39-0.80]	**0.90 [0.57-0.98]** / 0.40 [-0.50-0.80]

ICC; Interclass Correlation coefficient, CI; Confidence interval, E; Total variability, CE; Constant Error, AE; Absolute Error, VE; Variable Error

Table 5: Mean, standard deviation and Standard Error of Measurement between session for both groups

	SEM [°] between session 1 & 2					
	Set 1		Set 2		Set 3	
	Mean ± SD / Mean ± SD	SEM	**Mean ± SD** / Mean ± SD	SEM	**Mean ± SD** / Mean ± SD	SEM
E						
Most affected / dominant	**19.50 ± 7.45** / 6.71 ± 2.50	**3.94°** / 1.68°	**17.16 ± 7.77** / 5.88 ± 2.53	**4.98°** / 1.77°	**19.30 ± 9.56** / 4.63 ± 1.90	**3.17°** / 1.50°
Less affected / non-dominant	**11.59 ± 8.10** / 6.20 ± 2.08	**3.24°** / 1.36°	**11.10 ± 8.81** / 6.01 ± 2.84	**2.49°** / 1.24°	**11.86 ± 8.70** / 5.39 ± 2.16	**2.46°**/ 0.72°
CE						
Most affected / dominant	**-6.56 ± 16.68** / -9.93 ± 2.77	**8.50°**/ 1.41°	**-4.18 ± 16.42** / -3.49 ± 3.04	**7.70°** / 2.51°	**-5.97 ± 18.78** / -1.58 ± 2.63	**4.97°** / 1.51°
Less affected / non-dominant	**0.76 ± 12.57** / -2.68 ± 4.14	**4.87°**/1.71°	**3.57 ± 12.03** / -3.71 ± 5.07	**4.81°** / 1.90°	**3.60 ± 12.24** / -1.95 ± 3.81	**6.00°** /0.76°
AE						
Most affected / dominant	**17.52 ± 6.98** / 5.75 ± 2.30	**3.95°**/ 1.54°	**15.65 ± 7.72** / 4.72 ± 2.08	**5.18°** / 1.53°	**17.57 ± 9.63** / 3.79 ± 1.58	**3.05°**/ 1.24°
Less affected / non-dominant	**9.95 ± 8.26** / 5.25 ± 1.90	**3.50°**/ 1.19°	**9.68 ± 8.75** / 5.11 ± 2.75	**2.14°** / 1.17°	**10.48 ± 8.52** / 4.53 ± 1.99	**2.41°**/ 0.60°
VE						
Most affected / dominant	**10.09 ± 5.40** / 4.37 ± 1.26	**4.45°**/ 0.87°	**8.17 ± 3.69** / 4.28 ± 1.60	**1.38°** /1.27°	**8.75 ± 3.76** / 3.86 ± 1.32	**2.38°**/ 1.01°
Less affected / non-dominant	**6.69 ± 2.05** / 4.33 ± 1.09	**0.94°**/ 0.79°	**6.65 ± 2.33** / 4.04 ± 0.95	**1.07°**/ 0.78°	**5.73 ± 2.99** / 3.86 ± 1.32	**0.95°**/ 1.02°

SD; Standard deviation, SEM; Standard Error of Measurements, E; Total variability, CE; Constant Error, AE; Absolute Error, VE; Variable Error

Table 6: ICC values of the secondary outcome measures, between session reliability for the stroke group

	Stroke group							
	Most affected hand				Less affected hand			
	ICC	95%CI	SEM	Mean ± SD	ICC	95%CI	SEM	Mean ± SD
SWM								
Thumb	0.95	[0.84-0.99]	0.14	2.46 ± 1.47	0.95	[0.77-0.98]	0.12	3.46 ± 1.02
Index	0.92	[-0.48-0.89]	0.42	2.75 ± 1.33	0.91	[0.76-0.98]	0.19	3.54 ±1.22
RSTf								
DIP index	0.38	[-0.84-0.85]	0.84	7.19 ± 0.88	0.67	[-3.11-0.71]	0.82	7.29 ± 0.98
Distal ulnar processus	0.44	[0.20-0.93]	0.73	7.02 ± 1.06	0.38	[-3.15-0.70]	1.09	6.89 ± 0.95
EmNSA								
Light touch	0.95	[0.71-0.97]	0.14	7.56 ± 1.07	0.89	[-0.75-0.82]	0.29	7.7 ± 0.71
Pressure	0.77	[-1.22-0.82]	0.59	7.68 ± 0.97	0.89	[-1.18-0.81]	0.30	7.7 ± 0.71
Sharp	0.89	[0.65-0.97]	0.09	7.88 ± 0.43	1.00	[-2.28-0.70]	0.00	7.9 ± 0.20
Sharp/dull- discrimination	0.82	[-4.82-0.59]	0.86	7.46 ± 1.30	0	[0.95-1.00]	0.28	7.65 ± 1.09
Proprioception	0.93	[-0.35-0.84]	0.26	7.69 ± 0.88	0.89	[-0.21-0.87]	0.20	7.8 ± 0.57

SWM; Semmes-Weinstein Monofilaments, RSTF; Rydel Seiffer Tuning Fork, DIP; Distal interphalangeal joint, EmNSA; Erasumus modification of the Nottingham Sensory Assessment.

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UHASSELT

VOORTGANGSFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
11/10/17	Bespreking planning MP Deel 2	Promotor: Copromotor: Student(e): Student(e):
24/10/17	Voorlopige versie Instruction Booklet (handleiding)+ voorlopige versie introductie	Promotor: Copromotor: Student(e): Student(e):
09/11/17	Definitieve versie handleiding	Promotor: Copromotor: Student(e): Student(e):
15/11/17	Kennismaking + uitleg MIKE en protocol overlopen met Relab ETH Zurich te Diepenbeek (REVAL)	Promotor: Copromotor: Student(e): Student(e):
16/11/17	Pre-testing MIKE te Overpelt (MS center)	Promotor: Copromotor: Student(e): Student(e):
19/12/17	Start rekrutering CVA deelnemers in het St.Ursula ZH te Herk-de-Stad	Promotor: Copromotor: Student(e): Student(e):
28/12/17	Start testing CVA groep te Herk-de-Stad	Promotor: Copromotor: Student(e): Student(e):
19/01/18	Overleg MP Deel 2 + Testing CVA groep is voltooid	Promotor: Copromotor: Student(e): Student(e):
31/01/18	Robot (MIKE) naar MS center te Overpelt + excel bestand van data testbundels	Promotor: Copromotor: Student(e): Student(e):
06/02/18	Feedback research context, introductie en methode	Promotor: Copromotor: Student(e): Student(e):

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KNOWLEDGE IN ACTION

VOORTGANGSFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
29/03/18	Testing gezonde group te Overpelt + dataverwerking CVA groep (descriptieve en secundaire uitkomstmaten)	Promotor: Copromotor: Student(e): Student(e):
17/04/18	Data van CVA groep (MIKE, primaire uitkomstmaat) ontvangen uit Zurich	Promotor: Copromotor: Student(e): Student(e):
23/04/18	Resterende gezonde deelnemers nog te testen (2)	Promotor: Copromotor: Student(e): Student(e):
27/04/18	Research context, introductie en methode herschreven + start statistiek	Promotor: Copromotor: Student(e): Student(e):
03/05/18	Feedback van voorlopige versie MP deel 2	Promotor: Copromotor: Student(e): Student(e):
12/05/18	Data MIKE van gezonde deelnemers verzonden naar Zurich	Promotor: Copromotor: Student(e): Student(e):
14/05/18	Bespreking statistiek via skype	Promotor: Copromotor: Student(e): Student(e):
21/05/18	Herverwerking van introductie, methode, statistische analyse, resultaten en discussie	Promotor: Copromotor: Student(e): Student(e):
23/05/18	Masterproef overleg deel 2 (statistiek + tabellen)	Promotor: Copromotor: Student(e): Student(e):
		Promotor: Copromotor: Student(e): Student(e):

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Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen**
Jaar: **2018**

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