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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

The effect of Bimanual Intensive Movement Therapy (BIMT) on muscle strength of the upper limb in children with unilateral cerebral palsy

Demi Boeckx
Laurine Swennen

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

PROMOTOR :
Prof. dr. Eugene RAMECKERS

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Acknowledgement

This graduation project is a highlight of our Physiotherapy and Rehabilitation Sciences course at the University of Hasselt. The first part of this master thesis was a literature study wherein the obtained knowledge is used to write the second part of this master thesis which is a practical scientific study.

We would like to express our gratitude to everyone involved in our master thesis. First of all, we would like to thank our supervisor, Prof. Dr. Eugene Rameckers. Without his cooperation, guidance, feedback and academic support, the realization of this thesis would have been impossible.

Furthermore, we would like to thank 'REVAL' UHasselt, the department of rehabilitation and functioning UMaastricht, and the Adelante Rehabilitation Centre in Valkenburg for the collaboration and the opportunity to conduct this research.

Special thanks go to the children and their families, who enthusiastically participated to the summer camp and gave permission to carry out measurements for this research.

Last but not least, we want to mention our parents, family, friends and fellow students for the support and motivation during the process of this master thesis.

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Research context

This master thesis is situated in the research domain of neurological pediatric rehabilitation and is in line with earlier studies wherein Prof. Dr. E. Rameckers focused on the effect of bimanual intensive movement therapy (BIMT) on unimanual and bimanual activities in children with unilateral cerebral palsy (UCP).

The purpose of this research is to investigate the effect of BIMT on muscle strength of the upper limb (UL) in children with UCP. The main focus is muscle strength in the UL, whereas the Jebsen-Taylor Hand Function Test (JTHFT), Canadian Occupational Performance Measure (COPM), Abilhand-Kids, Goal Attainment Scale (GAS), and two functional strength tasks: the one-handed Cup- and two-handed Box-Task were added as secondary outcome measures.

Research on the effect of strength training in the UL in children with CP is influenced by the variability in frequency, intensity, duration and the type of exercise (E. Rameckers, Y. Janssen-Potten, I. Essers, & R. J. R. i. d. d. Smeets, 2015b). Previous studies showed that BIMT had a positive effect on the improvement of hand function in children with UCP (Sakzewski, Ziviani, & Boyd, 2014). Despite the scarce evidence of the effect of BIMT on muscle strength in these children, it has been shown that the UL function of children with UCP is mainly limited by muscle weakness (Braendvik, Elvrum, Vereijken, & Roeleveld, 2010; Brauers, Geijen, Speth, & Rameckers, 2017; K. Klingels et al., 2012). In addition, children with UCP are more likely to use their non-affected UL during functional activities leading to learned disuse of the affected hand, which negatively influences the affected UL function (Aarts, Jongerius, Geerdink, van Limbeek, & Geurts, 2010). Therefore, activities in daily life requiring bimanual UL activity, such as getting dressed, eating and preparing meals are difficult for these children (Brauers et al., 2017; K. Klingels et al., 2012; Lemmens et al., 2014) However, Rameckers et al. (2015) showed that strength training in combination with task-oriented therapy approaches resulted in an increased transfer to manual activities and an increased hand use in daily activities after the training period resulting in long term effects on grip and wrist strength. Consequently, we are interested in the effect of BIMT on muscle strength and functional outcome measures and the relation between these primary and secondary outcome measures at baseline.

This research is written according to the criteria of a rehabilitation scientific peer-reviewed journal and is conducted by two students physiotherapy and rehabilitation sciences at the University of Hasselt. Furthermore, there was a collaboration with 'REVAL' UHasselt, the department of rehabilitation and functioning UMaastricht, and the Adelante Rehabilitation Centre in Valkenburg.

The contribution of the students in the determination and elaboration of the research design and method was limited since the design was already set up within an existing research project. In addition, the recruitment and data acquisition for this study was already completed without the involvement of the students. However, to enhance the involvement, both students participated in a two-week summer camp wherein children with UCP received BIMT on an adventurous, challenging way. Furthermore, the students assisted four other master students to recruit children for their master thesis.

The data was analyzed, interpreted and processed independently by both students. Furthermore, academic writing was performed completely independent by the master students under supervision of the promotor. This master thesis was developed in equal collaboration between both partners.

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Content

1 Abstract

Background: Bimanual Intensive Movement therapy (BIMT) has a positive effect on the upper limb function in children with unilateral cerebral palsy (UCP), which is mainly limited by muscle weakness. However, research concerning the effect of BIMT on muscle strength of the upper limb in this population is scarce.

Objectives: To investigate the effect of BIMT on (functional) muscle strength, manual ability, hand dexterity, occupational performance, and goal achievement in children with UCP.

Participants: Forty-nine children aged 11 to 19 years (mean 15 years; 31 boys, 18 girls; 14 MACS I, 22 MACS II, 33 MACS III) participated to a summer camp consisting of eight hours therapy per day for 15 days. Individualized therapy was provided based on their arm-hand function goals which was expanded with group therapy in an adventurous theme.

Measurements: Body function measurements included muscle strength: grip, pinch, wrist extensor (WE), wrist extensor with flexion of the fingers (WEF), wrist flexion with flexion of the fingers (WFF), and functional muscle strength (Cup- and Box-Task). At activity level, the Abilhand-Kids, Jebsen-Taylor Hand Function Test (JTHFT), Canadian Occupational Performance Measure (COPM), and Goal Achievement Score (GAS) were investigated at baseline, immediately post, and six months after the intervention.

Results: Friedman Rank and Wilcoxon Each Pair tests revealed significant improvements. Considering the primary outcomes, only grip strength and WE showed significant improvements, whereas pinch strength, WEF and WFF showed no significant results. For secondary outcomes, Abilhand-Kids, JTHFT, COPM, GAS, and Box-Task improved significantly immediately post intervention and at follow-up. The Cup-Task showed significant improvements between the third and second measurement.

Conclusion: BIMT leads to unilateral and bimanual improvements of hand function in children with UCP which could be maintained or even improve significantly after the intervention. More research is needed to investigate the effect of BIMT on muscle strength.

2 Introduction

“Cerebral palsy (CP) is a neurodevelopmental disorder caused by a non-progressive lesion at one or more locations in the immature brain” (Charles, 2017). It includes permanent disorders of the development of movement and posture. CP occurs in the uterus, during birth or in the first two years of life and leads to limitations in activities of daily living, thereby substantially affecting the quality of life (Rosenbaum et al., 2007). CP has a prevalence between 1.5 and 3.8 per 1000 births reported worldwide which makes it the most common form of childhood disabilities (Ryan, Cassidy, Noorduyn, & O'Connell, 2017). In UCP, motor impairments are equally present in the upper and lower limb, but the effect of arm dysfunction is more pronounced wherein weakness is very prominent in the supinators, pronators, wrist extensors and flexors and finger flexors (Boyd et al., 2013; Klingels et al., 2012; Sakzewski et al., 2014). Next to the secondary impairments such as contractures and deformities, the primary impairments as spasticity, impaired motor control, and muscle weakness play a major role since this greatly limits UL functioning in activities of daily life (Koman, Smith, & Shilt, 2004). These UL activities include reaching, grasping and manipulating objects but also activities whereby children use their affected hand as assisting hand in order to carry out bimanual tasks (Brauers et al., 2017; Elvrum et al., 2012). The way children with CP use their hands to handle objects, described by the MACS, showed significant differences in the JTHFT and grip strength between the different MACS levels (Klingels et al., 2018). Furthermore, they prefer to use their uninvolved upper UL which leads to developmental disuse and disregard of the involved UL deteriorating the development of the involved extremity (Eliasson, Forssberg, Hung, & Gordon, 2006; Steenbergen, Verrel, & Gordon, 2007). Therefore, developmental disuse in combination with cerebral lesions cause muscle weakness of the affected limb and changes in the muscle fiber composition (Tilton, 2006). This muscle weakness of the upper and lower limb is negatively correlated with the execution of bimanual tasks (Brændvik, Elvrum, Vereijken, & Roeleveld, 2013; Brændvik & Roeleveld, 2012; Mockford & Caulton, 2010; Smits-Engelsman, Rameckers, & Duysens, 2004, 2005). In addition, the parietal lobe and supplementary motor area are involved in bimanual coordination and are often damaged in children with UCP (Duff & Gordon, 2003). Therefore, a bimanual structured intervention has been developed to focus on the coordination of the UL based on aspects of neuroplasticity and motor learning (Charles & Gordon, 2006; Gordon, Schneider, Chinnan, & Charles, 2007). BIMT was developed to respond to limitations found in Constraint Induced Movement

Therapy (CIMT), for example the inability to allow practice of bimanual skills (Sakzewski et al., 2011) and to target bimanual difficulties experienced in daily life which can be displayed by the COPM and GAS using predetermined and self-selected goals respectively. Research focusing on the effect of BIMT on muscle strength of the UL in children with CP is scarce. Bleyenheuft, Arnould, Brandao, Bleyenheuft, and Gordon (2015) examined HABIT-ILE whereby pinch-strength was one of the outcome measures. The intervention group had higher strength values with an improvement in pinch strength of 15% after 8 months. Sakzewski et al. (2011) examined grip strength in CIMT and BIMT. No significant difference in both hands was found between CIMT and BIMT at baseline, three or 26 weeks. Cohen-Holzer, Katz-Leurer, Reinstein, Rotem, and Meyer (2011) found a significant increase in grip and three-fingers pinch strength in the impaired hand and a significant increase in two-fingers pinch and key strength in both hands two months post-intervention (combination of CIMT with BIMT). Nour, Saleh, and Elnagmy (2016) investigated the effect of OT combined with/ and without mirror therapy. A significant difference in hand grip and pinch strength of the impaired hand was found in both groups, wherein an improvement of 84% and 157% for respectively hand grip and pinch strength was found eight weeks post-intervention. On the other hand, the effect of stand-alone upper limb strength training on strength in children with CP varies between 2.68% and 58.9% (McCubbin & Shasby, 1985; Reid, Hamer, Alderson, Lloyd, & Neurology, 2010) and the effect of strength training of the upper limb combined with other interventions varies between 41.8% and 84.68% after 3 months post training (Elvrum et al., 2012; Lee, You, Lee, Oh, & Cha, 2009; Rameckers et al., 2009; Vaz et al., 2008). Moreover, improvements after a task-oriented training can be due to an increase in UL involvement in daily activities (Rameckers et al., 2015). This transfer following rehabilitation to bimanual activities may be limited by bilateral hand deficits, even if subtle in the less-affected hand. Therefore, we are also interested in the effect of BIMT on the not- or less affected hand, although our main focus stays the affected hand (Rich, Menk, Rudser, Feyma, & Gillick, 2017). Additionally, no difference could be found between left- and right-sided hemiplegia on unimanual and bimanual performance measures (Sakzewski, Ziviani, & Boyd, 2010). Finally, evidence of long-term effects on muscle strength are currently lacking. Therefore, this study will mainly investigate the short- and long-term effects of BIMT on muscle strength in children with UCP. Whereas the COPM, Abilhand-Kids, JTHFT, GAS and the one-handed Cup and two- handed Box-Task are added as secondary outcome measures.

3 Methods

3.1 Participants

A clinical trial including a pre-post study design without a control group was set up in order to investigate the effect of BIMT on muscle strength of the upper limb in children with UCP. Between 2013 and 2018, six summer camps were organized whereby a total of 49 children participated at the ‘Hand in hand Survival Camp’ which took place in the Adelante Rehabilitation Centre in Valkenburg. The participants were recruited through several channels: the website of the international center of expertise called ‘Adelante’, a request from parents, registration via a colleague doctor or therapist, or children from own intern teams (school or rehabilitation). A different procedure was followed when children from other countries than The Netherlands or Belgium wanted to participate. They had to send a request and subsequently receive an approval after the first measurement which had to take place two to three months before the summer camp. Participants were selected according to the following criteria 1) 11-19 years of age, 2) unilateral spastic CP, 3) a clear personal goal about arm-hand function and 4) presence of minimal active grip function whereby children had the ability to open their hand (Zancolli 1 to 2B) and handle objects (MACS 1 to 4). Children were excluded in presence of the following criteria 1) history of uncontrolled seizures, 2) Tyltyl IQ < 90, 3) not able to speak English, German or Dutch or 4) had serious behavioral problems whereby therapists experienced difficulties during therapy. No approval is needed from the Medical Ethics Committee because the data were retrieved from a standard evaluation of this usual care rehabilitation program. In order to be allowed to use the acquired data, an informed consent had to be signed by parents and participants.

3.2 Interventions

The intervention took place at a 'Hand in hand Survival Camp' in the Adelante Rehabilitation Centre in Valkenburg, the Netherlands. The summer camp sleepover program lasted 15 days whereby participants received eight hours therapy per day, based on their personal needs and on activating the use of both hands during activities. Outdoor activities - as wall climbing, tree climbing, canoeing, archery and rowing - creative activities - as stone crafting, painting, and creating and decorating wooden boxes - but also activities of daily living such as preparing meals, cycling and tying shoelaces were part of the program. The program was individually tailored, took place in group or at individual level, and was based on pre-measurements and personal goals of the participant. If needed, the program could be adjusted after evaluation, which took place every evening together with all therapists and supervisors, to optimize their progression. All participants were accompanied with at least one or two physiotherapy students, occupational therapists or doctors and were supervised by the experienced therapists of Adelante. This summer camp is the sixth edition whereby an integration of the results from previous camps, conducted from July 2013 to July 2017 is carried out. Parents had the opportunity to stay in the area but did not participate with the activities. During the weekend and the last day, there was an exception, whereby they were allowed to join the program to enhance the transfer of learned skills to home or school situations. In addition, they received a home-based program with bimanual activities to further enhance their skills. The children could also bring their own physiotherapist whereby they could follow the progression or learn new treatment approaches about hand-arm rehabilitation.

All tests were measured at 3 moments: the first measurement took place 2 to 3 months before the summer camp, the second measurement was on the fifteenth and thus last day of the summer camp and the last one was after a follow up period of 6 months.

No additional information is provided about randomization, allocation or for example intention to treat since there was only one intervention group. The same assessors were used during pre- and post-intervention measurements and were not blinded since they supervised and administered training sessions. Furthermore, blinding of participants was not possible in this type of intervention.

3.3 Subgroup analysis

There is a lack of relevant studies indicating important differences in this age group wherein no important distinction could be made between children and adolescents in the applied age range (11-19 years of age). Furthermore, the GMFCS level and age cannot predict children's activity and participation because of the interaction between primary - and secondary impairments and environmental factors (Rodby-Bousquet, Paleg, Casey, Wizert, & Livingstone, 2016).

A subgroup analysis using Zancolli would not be relevant because of the uneven distribution, small number of children over different levels, whereby level 2B contained only 7 children, and the emphasis on deformity instead of the manual ability of children with UCP. This distribution of children was better concerning the MACS levels, although the number of children included per MACS level remained low. Additionally, MACS does not necessarily provide information concerning bimanual performance because the less-affected hand is allowed to perform the activities. Therefore, MACS levels should be interpreted with caution. Finally, Chounti, Hägglund, Wagner, and Westbom (2013) and Romeo et al. (2016) found no significant difference when comparing mean performance scores, gross motor function or manual ability between males and females. Furthermore, sex did not influence the severity of the impairment. Therefore, only the MACS remained of interest, which was used for the only subgroup analysis conducted in this study.

3.4 Outcome measures

3.4.1 Primary outcome measures

The effect on muscle strength was measured with the Biometric E-Link Evaluation System (Biometrics Ltd, Gwent UK) which measured the maximal grip and pinch strength in 100 grams increments. The E-Link evaluation system has an excellent validity, test-retest - and interrater reliability in children with UCP. The sensitivity and interrater reliability were increased by using a computerized dynamometer. In children with UCP from 7-12 years, an ICC of 0.940 (95% CI 0.896-0.965) and 0.937 (95% CI 0.895-0.962) and an ICC of 0.948 (95% CI 0.914-0.968) and 0.942 (95% CI 0.904-0.964) were found for the test-retest reliability for respectively pinch strength in the affected hand (AH) and non-affected hand (NAH) and grip strength in the AH and NAH. An ICC of 0.964 (95% CI 0.938-0.979) and 0.967 (95% CI 0.943-0.981) and an ICC of 0.976 (95% CI 0.959-0.986) and 0.960 (95% CI 0.932-0.977) were found for the interrater reliability for respectively pinch strength in the AH and NAH and grip strength in the AH and NAH. The smallest detectable change (SDC) for the AH is 3.47 kg for grip strength and 1.03 kg for pinch strength. The SDC for the NAH is 5.02 kg for grip strength and 1.41 kg for pinch strength. The E-Link is an easy, accurate, valid, and reliable instrument for measuring grip strength (Allen & Barnett, 2011; Dekkers, Janssen-Potten, et al., 2019).

In addition, the MicroFet2 hand-held dynamometer (HDD) (Hoggan Scientific, LLC, Salt Lake City UT, USA) was used to measure maximal isometric muscle strength of the long wrist extensors (WE), short wrist extensors (WEF), and short wrist flexors (WFF) whereby the applied force was measured in Newton. The HHD is a reliable instrument for measuring upper limb strength in children with CP (Dekkers, Rameckers, Smeets, & Janssen-Potten, 2014). An ICC between 0.894 (95% CI 0.814-0.940) and 0.964 (95% CI 0.938-0.979) and an ICC between 0.888 (95% CI 0.806-0.936) and 0.932 (95% CI 0.878-0.962) were found for the test-retest reliability for wrist flexion and extension for respectively the AH and NAH. An ICC between 0.840 (95% CI 0.724-0.908) and 0.963 (95% CI 0.932-0.980) and an ICC between 0.878 (95% CI 0.789-0.930) and 0.897 (95% CI 0.822-0.941) were found for the interrater reliability for wrist flexion and extension for respectively the AH and NAH. The SDC for the AH is 13.79 N for WE, 17.51 N for WEF, and 18.96 N for WFF. The SDC for the NAH is 23.22 N for WE, 30.89 N for WEF, and 24.54 N for WFF (Dekkers, Janssen-Potten, et al., 2019).

3.4.2 Secondary outcome measures

The one-handed Cup-Task and two-handed Box-Task offered additional information about the maximal weight (in grams) of a cup that could be lifted with a cylindrical grip (= maximal unilateral functional muscle strength), and the maximal weight in a box that could be lifted from the table with both hands (= maximal bilateral functional muscle strength) respectively. Dekkers, Smeets, et al. (2019) recently conducted a psychometric evaluation of these two new upper extremity functional strength tests in children with UCP between 7 and 12 years. The Cup-Task has an excellent test-retest reliability with an ICC of 0.887 (95% CI 0.713-0.948) and 0.944 (95% CI 0.895-0.969) for respectively the AH and NAH, an interrater reliability with an ICC of 0.960 (95% CI 0.918-0.980) and 0.898 (95% CI 0.825-0.941) for respectively the AH and NAH. The criterion validity between the Cup-Task and grip strength was moderate for the AH ($r=0.638$, $p \leq 0.001$) and low for the NAH ($r=0.489$, $p \leq .001$). The SDC is 787 grams and 755 grams for respectively the AH and NAH (Dekkers, Smeets, et al., 2019).

The Box-Task has an excellent test-retest reliability with an ICC of 0.934 (95% CI 0.875-0.963) and an interrater reliability with an ICC of 0.896 (95% CI 0.813-0.941). Furthermore, a moderate criterion validity between the Box-Task and grip strength AH ($r = 0.555$, $p \leq .001$) and a SDC value of 3.82 kg were found (Dekkers, Smeets, et al., 2019).

The Jebsen-Taylor Hand Function Test (JTHFT) is a standardized and objective test to evaluate unimanual upper extremity efficiency. The time used to complete all tasks is recorded, whereby movement speed is correlated with the capability of the child to use one hand. In this research, the JTHFT consists of six items (exclusion of the writing subtest), whereby a maximum of 120 seconds per item is set with a total of 720 seconds. The test consists of functional subtests such as manipulation and placement of small objects, simulated eating, empty and full can manipulation and card flipping (Friel et al., 2016), whereby the NAH is evaluated first (Araneda et al., 2019). Recently, a study assessing the reliability and responsiveness of the JTHFT in children with CP after a bimanual intensive intervention has been carried out. The test-retest reliability over a short time period (2 weeks) was excellent with an ICC value of 0.932 (95% CI 0.874-0.965) and 0.939 (95% CI 0.886-0.968) for respectively the AH and NAH. However, the test-retest reliability over a longer period (mean 120 days) was good for the AH with an ICC value of 0.784 (95% CI 0.529-0.910) but weak for the NAH with an ICC value of 0.284 (95% CI -0.173-0.644). The MCID was 54.7 seconds for the AH and 20.9 seconds for the NAH (Araneda et al., 2019).

Furthermore, the Abilhand-Kids is a questionnaire for parents/caregivers and measures the manual ability of children with all types of CP. The questionnaire contains 21 activities wherein parents rate their child's perceived difficulty and independency in performing one or two-handed activities on a three-level response scale (impossible, difficult, easy), whereby difficult activities can become a treatment goal during therapy. Children often have a more dichotomous perception of their own abilities and daily performance. Therefore, this kind of parent reported questionnaires are important in the assessment of clinical changes. The Abilhand-Kids is a reliable, valid and responsive instrument in detecting changes after intensive training in school-aged children with UCP. There is an excellent test- retest reliability with an ICC of 0.91, a validity with an ICC of 0.84 and 0.62 for children between 6 and 15 years and 12 and 16 years respectively, and an internal consistency with an ICC of 0.94 (James, Ziviani, & Boyd, 2014). Furthermore, an excellent intra-rater reliability with an ICC value of 0.92 (95% CI 0.87-0.96) (de Jong, van Meeteren, Emmelot, Land, & Dijkstra, 2018) and an excellent convergent validity with the MACS (r=-0.82), GMFCS (r=-0.74) (Makki, Duodu, & Nixon, 2014), and grip strength (r=0.64) (Klingels et al., 2012) could be found. For this reason, the Abilhand-Kids could be used as a performance and capacity-based rating method across different raters whereby the performance-based ratings were less reliable than the activity-based ratings when the parents completed the Abilhand-Kids (de Jong et al., 2018). Finally, the raw scores were converted to logits.

Another secondary outcome measure is the Canadian Occupational Performance Measure (COPM), which can be used in a wide variety of patients since there is no limit on age or diagnoses when using the COPM (Sakzewski, Boyd, & Ziviani, 2007). This test has two goals. The first one is to identify the most important problems in performing activities of daily living which will provide a guideline for rehabilitation. The second goal is to measure changes in the image the child has of his actions during the treatment process. This instrument can clarify patients' issues in areas of self-care, productivity, and leisure and is used to clarify the aims and individual goals. Moreover, children rate their perceptions of the importance of each identified problem on a scale from 1 to 10. Then the five most important problems are scored according to performance (P) and satisfaction (S). The scores of performance and satisfaction of the selected problems are summed and produce a score out of 10 (Carswell et al., 2004). The COPM reported a good responsiveness to detect meaningful clinical changes, an adequate to high test-retest reliability (ICC value between 0.76 and 0.89), and an excellent interrater reliability. On the other hand, no evidence for intra-rater reliability in children with cerebral palsy aged 5 to 13 years could be found (Sakzewski et al., 2007). The internal consistency reliability of total performance and total satisfaction scores indicated alpha 0.86 and 0.88 respectively, which indicates good construct validity derived from the high correlations indicating that items were cohesive. Furthermore, there is a minimum clinically important difference (MCID) of 2 points (Cusick, Lannin, & Lowe, 2007).

Lastly, the Goal Attainment Scale (GAS) was used at the beginning of the camp in order to quantify the individual progress towards the individual predetermined goals at the end of the camp. These goals were developed in collaboration with the supervisor and drawn up according to the SMART-principle (specific, measurable, acceptable, relevant and time-related). Setting personal goals may increase the motivation level and helps the children achieve progress in problems they experience in different areas of their life (Tam, Teachman, & Wright, 2008). The goals were related to improve bimanual everyday activities such as eating with knife and fork, riding a bike and to do the dishes. When using the GAS, the COPM can be used in combination to help the child plan the rehabilitation program by identifying goal priorities. The five most important goals are scaled on a five-point scale from -2 to +2: -2 is the initial pretreatment level, -1 represents progression towards the goal without goal achievement, 0 is the expected level of the goal after the program, +1 describes a greater outcome than expected and +2 is the best possible outcome that could have been expected for that goal (Krasny-Pacini et al., 2013). After the summer camp, a second and third GAS were filled in to measure whether these goals had been achieved and maintained. An excellent interrater reliability with an ICC value between 0.51 and 0.95, and an intra-rater reliability with an ICC value of 0.96 could be found. On the other hand, there is no evidence for internal consistency and test-retest reliability and results are variable for validity in children with CP aged 5 to 13 years (Sakzewski et al., 2007). A convergent validity assessment between the GAS and the COPM detected no correlation in children with CP (Cusick, McIntyre, Novak, Lannin, & Lowe, 2006). Furthermore, the GAS detects clinical important differences when a score equal to or more than zero was found (Steenbeek, Gorter, Ketelaar, Galama, & Lindeman, 2011).

3.5 Procedures of measurement

Primary outcome measurements were conducted while the participant was seated on a chair next to an adjustable table which supports the 90° flexed arm which was measured. The position had to be stable whereby the feet touched the floor and the back was supported. The child held the extremity in a neutral position (between pronation and supination and between flexion and extension) while the therapist was manually fixating the arm on the table. The wrist and hand were not supported. First the NAH was measured, then the AH.

3.5.1 Measurements of grip strength

The children were asked to squeeze as hard as possible to measure maximal isometric grip strength. Every trial was followed by 10 seconds rest after which the mean of three attempts was used in order to minimize the variation in muscle strength due to grasp or handling changes of the E-Link. This procedure was preceded with one attempt where the child could get used to the measurement. The therapist tried to encourage the child in order to produce maximal force, by saying “hard, harder, hardest” in a timespan of four to five seconds. If the child was not able to position the arm and hand in the desired position, the therapist was allowed to support the E-link so that this weight could not impede the measurement. The grip position was adjusted to the hand size of the child and was registered as position 1-2-3-4 or 5 (1 = smallest). If the neutral position was not possible, maximal supination was asked and the degree of pronation, ulnar deviation, wrist flexion and wrist extension were registered.

3.5.2 Measurements of pinch strength

The children were asked to pinch as hard as possible to measure maximal pinch strength. Every trial was followed by 10 seconds rest after which the mean of three attempts was used. The therapist tried to encourage the child during the test as previously mentioned. The thumb was located in the middle of the sensor and the fingers on the back of the E-Link. The child was allowed to practice the pinch grip if the thumb could easily slip off to prevent this during the test. If the neutral position was not possible, maximal supination was asked and the degree of pronation, ulnar deviation, wrist flexion and wrist extension were registered.

3.5.3 Measurements of isometric muscle force

Maximal isometric muscle force of the short wrist flexors and short and long wrist extensors was measured. The force was augmented during three to five seconds after which the child held this maximal force during one to two seconds. Every trial was followed by 15 seconds rest after which the mean of three attempts was used. The tester held the HHD in place during the test.

- To measure short wrist extensor strength, the HHD was placed on the back of the fist
- To measure long wrist extensor strength, the HHD was placed on the back of the open hand
- To measure wrist flexor strength, the HHD was placed on the palm of the open hand

The ‘make method’ was used wherein a difference of more than 20% indicates an inaccurate measurement whereby a new measurement was carried out. This was according to the Canadian protocol of Maltais and could be due for example to pain, motivation or fatigue (Hébert et al., 2011).

3.5.4 Measurements of secondary outcome measurements

3.5.4.1 Functional strength measurement

Two functional strength measurements, the one-handed Cup-Task and the two -handed Box-Task, were carried out.

During the one-handed Cup-Task, the cup was lifted with a cylindrical grip with the thumb next to or on the handle. The purpose of the test was to find out the maximal amount of water (displayed in grams) the child with UCP could lift with one hand and subsequently hold for five seconds. The cup had to be hold in a horizontal position, which could be checked by colored water and the tick marks on the cup. For a correct starting position, it was important that the top of the cup reached the iliac crest while the child was standing. First, the cup was lifted empty to determine the correct execution. Furthermore, 300 cc was added. If the child could not hold the cup for five seconds taking into account the prescribed conditions, 100 cc was removed, and the child had to try again after 60 seconds rest. 100 cc was again removed after the second failed attempt. This procedure had to be repeated until the child succeeded. If the child succeeded immediately after the first attempt, 100 cc was added. The water was replaced by weight bags when the amount of water in the cup reached 1000 cc. Finally, the maximal weight was determined when the child could just hold the cup for five seconds according to the prescribed conditions. First the NAH was tested, then the AH. During the task, elbow flexion, palmar flexion or ulnar deviation were allowed but had to be registered. However, an elbow flexion of 90 degrees and a neutral or radially deviated wrist position were preferred. Furthermore, the cup had to be controlled during the way back.

The second functional strength measurement was the two-handed Box-task whereby the box was held with a cylindrical grip with the thumb in or on top of the handle. The child was allowed to hold the box while the forearm was neutral or pro- or supinated and the wrist ulnar deviated. The degrees of the exact position were registered. The purpose of the test was to find out the maximal bilateral functional muscle strength. The starting position was similar to the position described in the one-handed Cup-Task. The box was positioned 10 cm from the edge of the table. First, the box was lifted empty to determine the correct execution whereby the child tried to hold the box with an elbow flexion of 90 degrees with the upper arms against the body. Deviations during the first two attempts were registered whereby the child had to try to lift the box with the same angle during the subsequent measurements. First, 500 grams were added using weight bags. If the child was not able to correctly execute this task for five seconds, 250 grams were removed, and the child tried again after 60 seconds rest. If the child succeeded immediately after the first attempt, 250 grams were added. This was repeated until the child could just lift the box without compensations. The child had to make sure that the box was held horizontally and not against the belly, did not slip out of 1 or 2 hands, and gently lowered after lifting.

4 Data analysis

We were interested in changes in activities, participation, and function two months before the intervention, immediately after the intervention, and whether these changes could be maintained after 6 months. The Friedman Rank test, a repeated measure model, was applied as a result of not normally distributed data which was assessed with the Shapiro-Wilk test. Pairwise post-hoc tests (The Wilcoxon Each Pair) were used to investigate time trends whereby a Bonferroni correction (0.05/3 = 0.017) was adopted. Multivariate normal imputation was executed with JMP software which provided a least squares prediction from the non-missing variables in each row.

The Friedman Rank test and Wilcoxon Each pair were likewise conducted for each outcome variable while taking into account the MACS level and time trend. Furthermore, we were interested in baseline correlations of all outcome measures in order to compare the degree of correlation with the increase or decrease of the outcome measures at the second and third measurement. This was conducted using Spearman's rank correlation coefficients (r_s) which were classified as no or little (0.00-0.25), fair (.25-.50), moderate to good (.50-.75) or good to excellent (>.75) (Portney & Watkins, 2009).

Descriptive statistics were used to display baseline characteristics and primary and secondary outcome measures over time using means and standard deviations on different time points.

A significance level of 0.05 was used for all statistical analyses except for the Wilcoxon Each Pair as earlier mentioned. All statistical analyses were performed using JMP software, version 14.1 SAS Inst. Inc., Cary, NC, USA.

5 Results

5.1 Participants

Subject characteristics are displayed in Table 1. Forty-nine children with UCP were included (31 boys, 18 girls) with a mean age of 15 years (SD= 1.76). Hemiplegia was left-sided in 22 subjects and right-sided in 27 subjects. According to the MACS levels, 14 subjects were classified as MACS I, 22 as MACS II, and 13 as MACS III. According to the Zancolli classification, 19 children were classified in level I, 23 in IIA and 7 in IIB. The majority of the children had a GMFCS level I (44), whereas 5 children had a GMFCS level II.

Baseline measurements are displayed in Table 2 wherein mean and standard deviations are displayed for all outcome measures.

5.2 Effect of BIMT on muscle strength

The mean, standard deviation and statistical comparisons over time are reported in Table 2. A significant change, following BIMT, could be found for grip strength (AH) (p=0.0171) and WE (AH) (p=0.001) + (NAH) (p=0.0198). Significant short-term changes, whereby a comparison was made between the first and second measurement, are present for WE. The AH showed a significant improvement (p <.0001) with 47.22%, the NAH a significant decline (p=0.0009) with 19.46%.

When evaluating long-term results, a comparison was made between the first and third measurement but also the second and third measurement. Grip strength (AH) showed significant improvements compared with the second (p=0.0019) and compared with the first measurement (p=0.0045) with 19.61% and 20.99% respectively. However, WE (AH+NAH) only showed significant changes when comparing the third and second measurement. The AH showed a significant decline (p=0.0106) with 14.20% and the NAH showed a significant improvement (p=0.0003) with 24.60%. Furthermore, no significant long or short-term changes could be found for pinch strength, WEF (AH+NAH), or WFF (AH+NAH).

Figure 1 displays the improvement/decline and significance of every outcome measure together with the mean on three different measuring moments.

5.3 Effect of BIMT on secondary outcome measures

A significant change could be found for Abilhand-Kids (p=0.0026), COPM (P) (p<.0001) + (S) (p<.0001), GAS (p<.0001), JTHFT (AH) (p=0.0022) + (NAH) (p<.0001), and functional strength measurements divided in the Cup-Task (AH) (p=0.7687) and Box-Task (p=<.0001). Significant short-term improvements, whereby a comparison was made between the first and second measurement, are present for Abilhand-Kids (p=0.0006) with 15.59%, COPM (P+S) (p<.0001) with 82.80%, GAS (p<.0001), JTHFT (AH) (p=0.0105) with 10.70% and (NAH) (p<.0001) with 9.61%, and the Box-Task (p=0.0019) with 19.56%.

When evaluating long-term results, a comparison was made between the first and third measurement but also the second and third measurement. Significant improvements for both comparisons were found for the JTHFT (AH+NAH). The JTHFT showed significant improvements compared with the second measurement for the AH (p=0.0140) with 2.32% and the NAH (p=0.0004) with 8.12% and compared with the first measurement (p<.0001) for the AH with 12.77% and NAH with 16.95%. The COPM showed a significant decline when comparing the third and second measurement (p<.0001) with 4.77% and 6.31% for respectively P and S. However, a significant improvement could be found for P and S when comparing the third and first measurement (p<.0001) with 74.08% and 71.25% respectively.

However, the Abilhand-Kids and GAS only showed significant long-term improvements (p<.0001) when comparing the third and first measurement with 23.55% for the Abilhand-Kids, whereas the Cup-Task (AH) only showed significant improvements when comparing the third and second measurement (p=0.0035) with 30.72%.

5.4 Smallest detectable change (SDC) and minimal important change (MIC)

It is important to take the SDC an MIC into account to interpret results. The SDC is defined as 'the smallest change that can be detected by the instrument beyond measurement error' and the MIC as 'the smallest change in the construct to be measured, which are perceived as important by patients, clinicians, or relevant others' (de Vet & Terwee, 2010).

Change scores were calculated by subtracting the third and first measurement and the third and second measurement for each participant. These change scores were compared with the SDC and MIC whereby a percentage showing the number of participants reaching these values is mentioned below for the earlier mentioned significant improvements.

Percentage of children showing changes higher than the SDC or MIC between the first and second measurement:

- WE: 38.78% and 4.08% for the AH and NAH respectively
- Box-Task: 16.33%
- JTHFT: 26.53% and 4.08% for the AH and NAH respectively
- COPM: 91.84% and 89.80% for P and S respectively

Percentage of children showing changes higher than the SDC or MIC between the first and third measurement:

- Grip strength: 24.49% for the AH
- Box-Task: 36.73%
- JTHFT: 16.33% and 8.16% for the AH and NAH respectively
- COPM: 89.80% and 83.67% for P and S respectively

5.5 Analysis by MACS level

The mean, standard deviation, and statistical comparisons over time taking into account different MACS levels are reported in Table 3.

Significant changes, for at least one MACS level, are present in grip strength (AH+NAH), WE (AH+NAH), Abilhand-Kids, and the Box-Task. Furthermore, the COPM (P+S), GAS, and JTHFT (AH+NAH) show significant changes for all MACS levels. On the other hand, the Cup-Task showed significant results which could not be seen with a division per MACS level.

In Figure 3, there is a trend indicating an association between a higher MACS level and less muscle strength. However, WE (NAH) and WEF (NAH) show a different and variable trend. In Figure 4, it is more complicated to find a common trend. The COPM and GAS have a very similar trend. However, the significant decline for the COPM was mainly present for MACS level III. This could not be seen for the GAS wherein only a trend indicating this decline could be found for MACS level II.

5.6 Relationship between muscle strength and secondary outcome measures

The Spearman's correlation coefficients (r_s) and corresponding p-values for all primary and secondary outcome measures are reported in Table 4. Significant correlations varying from little or no (r_s = 0.00 - 0.25) to good to excellent (r_s > 0.75) were found.

Correlation coefficients between primary outcome measures showed stronger correlations in the AH compared with the NAH. For WE, moderate to good correlations (r_s = 0.50-0.75) were found with WFF and grip- and pinch strength. Also, for WEF correlated with WFF and grip- and pinch strength and for WFF correlated with grip- and pinch strength. A good to excellent correlation (r_s > 0.75) was found for WE with WEF and for grip strength with pinch strength. Correlation coefficients between primary outcome measures showed more fair correlations (r_s = 0.25 - 0.50) in the NAH. Fair correlations were found for pinch strength correlated with grip strength, WFF and WEF but also for WE correlated with grip-strength and for WEF correlated with WFF and grip strength. Although, moderate to good correlations were found for WFF with WE and with grip strength. Furthermore, one good to excellent correlation was found for WE with WEF.

Correlation coefficients between secondary outcome measures were moderate to good for COPM P with S and good to excellent for JTHFT (AH) with the Cup-Task (AH) and JTHFT (NAH) with the Cup-Task (NAH). Finally, correlation coefficients between primary and secondary outcome measures were moderate to good for the JTHFT (AH) correlated with WE, WEF, WFF, and pinch strength. Also, for the Box-Task correlated with grip strength (AH) and pinch strength (AH) and for the Cup-Task (AH) correlated with WE, WEF, WFF, and pinch strength, and for the Cup-Task (NAH) correlated with grip strength.

6 Discussion

Research concerning the effect of BIMT on muscle strength and functional outcome measures in children with UCP is not yet investigated extensively. Therefore, the effect of BIMT on muscle strength was the main objective of this research. Additionally, outcome measures on activity and participation level were added as secondary outcomes. Results were achieved by collecting outcome measurements of BIMT-camps conducted over the past six years (2013-2018). Furthermore, a subgroup analysis per MACS level was carried out in order to investigate significant differences per MACS level which categorizes and displays the ability of children with UCP to participate in daily life (Eliasson & Burtner, 2008).

When the Friedman Rank Test was not significant, the Wilcoxon Each Pair was still carried out. This could reveal the variable progression of outcome measures whereby there could be a significant decline followed by a significant improvement or vice versa.

Significant results concerning the primary outcome measure could only be found for grip strength (AH) and WE (AH + NAH), whereas this could not be found for pinch strength, WEF, and WFF. Grip strength showed significant long- term results whereby there was a significant improvement when the third measurement was compared with baseline, but on top of that, grip strength improved significantly during the follow-up period after the intervention. On the other hand, WE significantly improved when comparing the third and second measurement for the NAH, while it significantly declined during this period for the AH. The opposite was found when comparing the first and second measurement, whereby a significant decline was shown for the NAH and a significant improvement for the AH. It can be concluded that WE in the AH only showed short-term improvements which disappeared after the intervention. Primary outcome measures have to be interpreted carefully. Muscle strength at baseline is in this research sometimes already smaller than the SDC-value. This makes it unlikely that an intervention will achieve improvements higher than the SDC-threshold and can possibly explain the low percentages of children achieving an improvement in WE or grip strength (AH) higher than the SDC-threshold (Dekkers, Janssen-Potten, et al., 2019).

When focusing on the secondary outcome measures, it can be concluded that all outcomes, except the Cup-Task (AH + NAH), showed significant short-term improvements. This is in line with the study of Gordon et al. (2011) and Green et al. (2013) wherein a significant short-term improvement could be found for the JTHFT (AH) and with the study of Speth et al. (2015) who found a significant positive effect on goal achievement measured at 12, 18, and 24 weeks.

The Abilhand-Kids showed significant short-term improvements which could be maintained until the third measurement but did not improve significantly between the third and second measurement. This is not completely in line with the study of Hines, Bundy, Black, Haertsch, and Wallen (2019) which could only find a significant improvement when comparing the first and last (6 months post intervention) measurement for the Abilhand-Kids. Furthermore, Bleyenheuft, Gordon, Rameckers, Thonnard, and Arnould (2017) found larger changes in children with MACS level II, whereas in this current research, this could be found for children with MACS level I.
A significant improvement in the follow-up period, was found for the JTHFT (AH + NAH) and the Box- and Cup-Task (AH). Therefore, these skills are mainly improved after the intervention which can possibly be explained by an increased involvement of the AH in daily live after the intervention. This is in line with the study of Hines et al. (2019), Green et al. (2013), and Gordon et al. (2011) wherein unimanual ability (JTHFT) improved significantly at follow-up. On the other hand, the COPM (P + S) showed a significant decline between the second and third measurement. This means that children were less satisfied with their predetermined goals and their performance. However, the follow-up measurements were still significantly better compared with baseline. This is in line with Hines et al. (2019) and Sakzewski, Provan, Ziviani, and Boyd (2015) who found significant improvements for COPM (P + S) from baseline to all follow-up measurements. Although, no comparison between the second and third measurement was made by these studies.

It can be concluded that comparisons between the degree of correlation at baseline and the significant improvement or decline found, immediately post-intervention or at follow-up, barely correspond. A moderate to good correlation was found for JTHFT (AH) with WE, WEF, WFF, and pinch strength, whereby significant improvements could only be found for JTHFT (AH) and WE. Despite a significant good to excellent correlation between WE and WEF and a moderate to good correlation between WE and WFF at baseline, no similar significant improvements could be found for WEF or WFF. Finally, despite a significant good to excellent correlation between pinch- and grip strength at baseline, no such improvements could be found for pinch strength. This can be due to the amount and kind of activities wherein grip strength was used during the intervention, which was remarkably higher compared with pinch strength.

The Box-Task had a moderate to good correlation with grip strength (AH) in this study which is in line with the study of Dekkers, Smeets, et al. (2019). On the other hand, the Cup-Task (AH) had a good to excellent correlation with grip strength (AH) in this study but was only moderate in the study of Dekkers, Smeets, et al. (2019)

Furthermore, according to Klingels et al. (2018), it has to be taken into consideration that there could be significant improvements for JTHFT (AH + NAH) and grip strength (NAH) between baseline and one-year follow-up without a specific intervention. The natural progression of these outcome measures can therefore influence the long-term results achieved after the BIMT- intervention.

Several limitations should be noted. This was a self-control study wherein data was not normally distributed and a Bonferroni correction was used which all resulted in reduced statistical power. Despite the amount of missing values, no single drop- out could be reported during the intervention. However, missing values increased towards the second and even more towards the third measurement. Detailed information concerning the reason of a missing values could not always be retrieved. Therefore, multivariate normal imputation was executed with JMP software (version 14.1 SAS Inst. Inc., Cary, NC, USA), which provided a least squares prediction from the non-missing variables in each row.

Psychometric characteristics of all measurements used in this current research are previously carefully described whereby all outcomes were valid (except for the HHD and JTHFT), reliable and responsive. However, caution should be taken for the Abilhand-Kids, wherein manual ability is scored by parents only and calibrated for children from 6 to 15 years. However, in this research, children were aged between 11 and 19 years and scored the Abilhand-Kids themselves which is reported to be less sensitive since children were older than 15 years (Bleyenheuft et al., 2017). Finally, psychometric properties for the E-Link are only investigated in children with UCP aged between 7 and 12 years.

All measurements were conducted by experienced assessors who remained the same over the past 5 years. However, assessors were not fully blinded because they assisted and supervised the activities provided during the intervention. On top of that, therapists and children could not be blinded either. Furthermore, the second measurement took place on the last day of the intervention, whereby children could be exhausted from activities conducted during the camp. Additionally, no attention was given to the sequence of measurements which can possibly influence the results.

Furthermore, isometric strength measurements could be influenced by impaired selective motor control and excessive co-contraction, which may reduce the potential agonist force (Damiano, Dodd, & Taylor, 2002).

More attention should be paid to the amount of wrist flexion or extension during the isometric strength measurements. The study of Vaz, Cotta, Fonseca, and De Melo Pertence (2006) found significant less flexor and extensor strength in an extended wrist position compared with neutral or 30° wrist flexion. Furthermore, significant more flexor strength could be found in 30° wrist flexion compared with a neutral wrist position. This can be due to a shift in the length-tension curves in these muscle groups. Furthermore, maximal isometric contractions measured in this current research, can only provide information about the strength that can be produced in that condition and for that certain muscle length. Therefore, this could not be generalized to situations wherein muscle length is different or changing during the task Damiano et al. (2002). On the other hand, use of the affected arm in bimanual performances can be well predicted by grip strength measurements (Braendvik et al., 2010; Klingels et al., 2012).

This research unveiled a number of limitations and recommendations for further research. First of all, a selection bias is present because children included in this research were often students of the school where the BIMT-camp took place. Furthermore, only children with mild to moderate motor impairments in the upper limb function were included. Therefore, generalization of results to all children with UCP is not possible. Group-based therapy, wherein the task was quite similar for all children, was provided. On top of that, individual therapy, wherein children trained their personal goals, was modified to their progression and needs. Additionally, children continued their usual therapy after the intervention. This resulted in a performance bias because the exact content of the intervention differed and could not be described accurately. Finally, a detection bias is present because there is a lack of blinding of assessors, participants, and therapists.

It should also be taken into account that there are differences between acquired and congenital lesions influencing muscle strength and grip strength (Klingels et al., 2012). Furthermore, it is advised to include more children per MACS level when using this for a subgroup analysis in order to increase the statistical relevance. On the other hand, Geijen et al. (2018) advised cut off points per isometric strength level to divide children with CP into groups which could be even more appropriate.

Finally, it would be interesting to use The Assisting Hand Assessment (AHA) in children with unilateral disabilities in this research in order to describe the effectiveness of their affected hand use during bimanual activities.

7 Conclusion

In this research, BIMT showed to be effective in increasing grip strength (AH) and muscle strength of the wrist extensors (AH + NAH). Grip strength of the AH improved after 2 months but was only significant after 6 months. WE of the AH improved after 2 months but showed a significant decline after 6 months whereby the exact opposite was found for WE of the NAH. Functional muscle strength (Box-Task), manual ability (Abilhand-Kids), occupational performance (COPM), goal achievement (GAS), and dexterity (JTHFT) improved significantly on short- and long term. However, the COPM showed a significant decline regarding the performance and satisfaction between the third and second measurement.

Taking the MACS level into consideration, there is a trend indicating that children with a lower MACS level tend to have less muscle strength. However, this could not be applied on WE (NAH) and WEF (NAH) or secondary outcome measures. In conclusion, BIMT has shown to lead to unilateral and bimanual improvements of hand function in children with UCP.

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9 APPENDIX

9.1 Tables

Table 1:
Baseline participants characteristics

Characteristics		
Mean age in years		15
Gender	Male	31
	Female	18
Paretic upper extremity	Right	22
	Left	27
MACS	I	14
	II	22
	III	13
GMFCS	I	44
	II	5
Zancolli	I	19
	IIA	23
	IIB	7

MACS: Manual Ability Classification System; GMFCS: Gross Motor Function Classification System

Table 2:

Mean, corresponding standard deviation and statistical comparison over time

		Time Mean (SD)			Friedman		Wilcoxon					
							M1 vs M2		M2 vs M3		M1 vs M3	
		M1	M2	M3	P-waarde	ChiSquare	Z-waarde	P-waarde	Z-waarde	P-waarde	Z-waarde	P-waarde
WE (gram)	AH	33.79 (27.02)	49.74 (24.25)	42.67 (33.03)	0.0010*	13.8617	4.32713	<.0001*	-2.55433	0.0106*	1.96461	0.0495
	NAH	95.09 (36.73)	76.58 (30.28)	95.42 (30.50)	0.0198*	7.8446	-3.30751	0.0009*	3.65208	0.0003*	0.85973	0.3899
WEF (gram)	AH	43.48 (33.23)	44.29 (31.82)	49.92 (34.24)	0.5414	1.2273	0.628857	0.5294	0.937906	0.3483	1.417521	0.1563
	NAH	107.25 (38.32)	103.47 (29.90)	106.93 (70.34)	0.6703	0.8000	-0.362373	0.7171	-0.206051	0.8368	-0.504470	0.6139
WFF (gram)	AH	50.67 (26.43)	53.83 (25.82)	60.86 (34.98)	0.8231	0.3895	1.019624	0.3079	1.399735	0.1616	2.330516	0.0198
	NAH	93.10 (26.09)	98.28 (24.51)	103.65 (51.38)	0.4051	1.8075	1.925549	0.0542	0.412105	0.6803	1.900650	0.0573
Grip (gram)	AH	8.38 (6.65)	8.48 (7.38)	10.14 (8.59)	0.0171*	8.1376	-0.16698	0.8674	3.10500	0.0019*	2.83855	0.0045*
	NAH	27.02 (9.20)	25.79 (10.15)	25.86 (8.20)	0.0679	5.3789	-2.31278	0.0207	2.14579	0.0319	-0.32329	0.7465
Pinch (gram)	AH	3.02 (1.93)	3.24 (2.29)	3.16 (2.16)	0.6554	0.8449	-0.309094	0.7572	-0.206058	0.8367	-0.472498	0.6366
	NAH	6.71 (2.01)	7.05 (2.83)	6.56 (2.20)	0.1480	3.8211	1.22923	0.2190	-1.48857	0.1366	-0.29132	0.7708
Abilhand-Kids (logits)	AH	3.69 (1.68)	4.24 (1.60)	4.53 (1.49)	0.0026*	11.9088	3.414253	0.0006*	1.682503	0.0925	4.590294	<.0001*
COPM	P	4.32 (1.14)	7.9 (0.77)	7.53 (0.82)	<.0001*	78.4255	8.52680	<.0001*	-2.59425	0.0095*	8.51275	<.0001*
	S	4.46 (1.17)	8.16 (0.84)	7.65 (0.73)	<.0001*	80.4574	8.52756	<.0001*	-4.08343	<.0001*	8.47434	<.0001*
GAS		-2 (0)	0.33 (0.63)	0.29 (0.58)	<.0001*	90.0500	8.66469	<.0001*	-0.21568	0.8292	8.66655	<.0001*
JTHFT (seconds)	AH	266.96 (188.92)	238.40 (168.61)	232.87 (167.72)	0.0022*	12.2769	-2.55789	0.0105*	-2.45842	0.0140*	-4.84935	<.0001*
	NAH	47,15 (13.30)	42.62 (11.11)	39.16 (8.55)	<.0001*	25.2680	-3.92567	<.0001*	-3.53842	0.0004*	-6.42672	<.0001*
Box task (gram)		8288.78 (7189.59)	9910.20 (7728.75)	12838.78 (13514.62)	<.0001*	27.8343	3.100037	0.0019*	3.056186	0.0022*	5.628870	<.0001*
Cup task (gram)	AH	645.69 (853.73)	583.88 (793.85)	763.27 (972.16)	0.7687	0.5261	-1.01058	0.3122	2.92049	0.0035*	2.03588	0.0418
	NAH	3326.53 (1324.57)	3346.94 (1400.16)	3562.96 (1210.54)	0.2197	3.0314	0.524217	0.6001	1.482698	0.1382	1.849583	0.0644

WE: wrist extension; WEF: wrist extension with finger flexion; WFF: wrist flexion with finger flexion; Grip: grip strength; Pinch: pinch strength; COPM: Canadian Occupational Performance Measure; P: Performance; S: Satisfaction GAS: Goal Attainment Scale; JTHFT: Jebsen Taylor Hand Function Test; AH: Affected Hand; NAH: Non- Affected Hand; M1: first measurement; M2: second measurement; M3: third measurement;

Table 3:

Mean, corresponding standard deviation and statistical comparison over time per MACS

						Friedman		Wilcoxon					
			Time Mean (SD)					M1 vs M2		M2 vs M3		M1 vs M3	
			T1	T2	T3	P-waarde	ChiSquare	Z-waarde	P-waarde	Z-waarde	P-waarde	Z- waarde	P-waarde
WE (gram)	**AH**	**MACS 1**	56.88 (25.13)	65.38 (22.73)	62.31 (42.71)	0.3967	1.8491	1.953311	0.0508	-1.309509	0.1904	0.229770	0.8183
		MACS 2	28.14 (24.60)	46.40 (22.84)	40.72 (27.32)	0.0676	5.3882	2.617382	0.0089*	-1.009358	0.3128	1.795656	0.0725
		MACS 3	18.47 (15.55)	38.55 (20.92)	24.83 (16.77)	0.0198*	7.8400	3.230769	0.0012*	-2.25641	0.0240	1.231190	0.2183
	NAH	**MACS 1**	88.02 (33.78)	71.87 (31.28)	103.24 (30.01)	0.0324*	6.8571	-1.447352	0.1478	2.596044	0.0094*	1.906829	0.0565
		MACS 2	107.08 (41.81)	75.76 (34.75)	94.19 (35.90)	0.0314*	6.9195	-3.708806	0.0002*	1.889546	0.0588	-1.138422	0.2549
		MACS 3	82.41 (24.56)	83.05 (20.53)	89.07 (19.27)	0.2780	2.5600	0.359097	0.7195	1.538462	0.1239	1.589744	0.1119
WEF (gram)	**AH**	**MACS 1**	62.76 (34.40)	64.10 (32.88)	72.62 (35.74)	0.1738	3.5000	0.735465	0.4621	-0.091908	0.9268	0.758137	0.4484
		MACS 2	41.81 (33.18)	42.82 (31.53)	46.17 (31.20)	0.5802	1.0886	0.340425	0.7335	0.680730	0.4960	0.821571	0.4113
		MACS 3	25.53 (20.54)	25.45 (17.08)	31.84 (24.91)	0.7491	0.5778	0.256586	0.7975	0.692426	0.4887	0.820793	0.4118
	NAH	**MACS 1**	104.25 (30.97)	100.43 (31.04)	106.02 (34.91)	0.7436	0.5926	-0.436622	0.6624	1.033823	0.3012	0.482451	0.6295
		MACS 2	113.42 (45.43)	111.14 (30.62)	118.10 (98.78)	0.8302	0.3721	0.363851	0.7160	-0.082154	0.9345	-0.152572	0.8787
		MACS 3	100.06 (32.97)	93.76 (25.92)	88.99 (28.61)	0.2187	3.0400	-0.512996	0.6080	-1.076923	0.2815	-1.641026	0.1008
WFF (gram)	**AH**	**MACS 1**	64.78 (30.27)	71.93 (28.60)	74.33 (29.88)	0.4975	1.3962	1.470930	0.1413	0.436503	0.6625	1.952776	0.0508
		MACS 2	46.51 (25.40)	48.35 (24.07)	62.36 (40.50)	0.7332	0.6207	0.305155	0.7602	1.819129	0.0689	2.147745	0.0317
		MACS 3	42.52 (18.32)	43.62 (14.70)	43.81 (22.94)	0.4771	1.4800	-0.025645	0.9795	-0.538554	0.5902	-0.307692	0.7583
	NAH	**MACS 1**	104.50 (34.76)	110.36 (26.45)	131 (80.86)	0.8763	0.2642	0.965298	0.3344	0.436503	0.6625	1.309509	0.1904
		MACS 2	93.88 (20.43)	95.49 (22.71)	97.48 (31.88)	0.4546	1.5765	0.410800	0.6812	0.903696	0.3662	1.173673	0.2405
		MACS 3	79.50 (18.15)	89.97 (22.00)	84.63 (19.09)	0.2880	2.4898	1.974697	0.0483	-0.974692	0.3297	0.871795	0.3833
Grip (gram)	**AH**	**MACS 1**	13.74 (7.64)	15.53 (8.83)	15.56 (8.77)	0.0877	4.8679	1.930595	0.0535	0.022977	0.9817	2.320675	0.0203
		MACS 2	6.94 (5.52)	6.66 (4.88)	9.48 (9.04)	0.0802	5.0465	-0.211261	0.8327	2.629027	0.0086*	2.124273	0.0336
		MACS 3	5.05 (3.34)	3.97 (2.39)	5.43 (3.17)	0.0529	5.8800	-2.128569	0.0333	2.282441	0.0225	0.256410	0.7976
	NAH	**MACS 1**	32.81 (11.48)	32.98 (12.67)	30.67 (9.67)	0.8007	0.4444	0.114901	0.9085	-0.804084	0.4213	-0.528398	0.5972
		MACS 2	25.49 (6.92)	23.56 (6.97)	24.50 (6.77)	0.1789	3.4419	-2.312217	0.0208	2.617198	0.0089*	0.563363	0.5732
		MACS 3	23.37 (7.32)	21.83 (8.19)	22.98 (6.93)	0.3198	2.2800	-1.513079	0.1303	1.538988	0.1238	-0.410256	0.6816
Pinch (gram)	**AH**	**MACS 1**	4.29 (2.37)	4.06 (1.87)	4.10 (1.90)	0.9813	0.0377	-0.712774	0.4760	0.183841	0.8541	-0.34460	0.7304
		MACS 2	2.96 (1.60)	2.98 (1.71)	3.32 (2.35)	0.7788	0.5000	-0.481257	0.6303	0.586836	0.5573	0.129099	0.8973
		MACS 3	1.77 (0.81)	2.77 (3.31)	1.87 (1.49)	0.2322	2.9200	0.948880	0.3427	-1.487688	0.1368	-0.205128	0.8375

	NAH	**MACS 1**	7.91 (2.42)	8.41 (3.01)	7.97 (2.92)	0.3818	1.9259	1.493708	0.1353	-0.987875	0.3232	0.758137	0.4484
		MACS 2	6.93 (1.70)	6.56 (2.01)	6.28 (1.51)	0.2848	2.5116	0.575120	0.5652	-0.927169	0.3538	-0.363826	0.7160
		MACS 3	5.94 (1.50)	6.43 (3.49)	5.50 (1.59)	0.8694	0.2800	-0.076936	0.9387	-0.846299	0.3974	-0.923077	0.3560
Abilhand-Kids (logits)	**AH**	**MACS 1**	4.07 (1.84)	4.91 (1.51)	5.36 (1.52)	0.7485	0.5794	2.254527	0.0242	1.069607	0.2848	2.975463	0.0029*
		MACS 2	3.30 (1.77)	4.21 (1.46)	4.36 (1.48)	0.0018*	12.6870	3.861640	0.0001*	0.659632	0.5095	4.108733	<.0001*
		MACS 3	3.86 (1.27)	3.58 (1.72)	3.93 (1.11)	0.7225	0.6500	-0.616651	0.5375	0.927207	0.3538	0.333847	0.7385
COPM	**P**	**MACS 1**	4.30 (0.83)	7.75 (0.79)	7.57 (0.51)	<.0001*	23.1111	4.48174	<.0001*	-1.05781	0.2901	4.48174	<.0001*
		MACS 2	4.38 (1.23)	7.95 (0.76)	7.72 (0.73)	<.0001*	35.5714	5.66864	<.0001*	-1.00968	0.3126	5.66904	<.0001*
		MACS 3	4.26 (1.34)	8.01 (0.79)	7.17 (1.11)	<.0001*	22.2400	4.30843	<.0001*	-2.28557	0.0223	4.30843	<.0001*
	S	**MACS 1**	4.35 (1.03)	8.17 (0.71)	7.67 (0.60)	<.0001*	25.4815	4.48051	<.0001*	-2.52989	0.0114*	4.48051	<.0001*
		MACS 2	4.53 (1.32)	8.08 (0.97)	7.76 (0.68)	<.0001*	35.3176	5.66884	<.0001*	-1.65540	0.0978	5.66944	<.0001*
		MACS 3	4.48 (1.11)	8.28 (0.80)	7.42 (0.93)	<.0001*	20.3673	4.31582	<.0001*	-2.59909	0.0093*	4.23584	<.0001*
GAS		**MACS 1**	-2 (0)	0.36 (0.63)	0.43 (0.51)	<.0001*	25.0638	4.524699	<.0001*	0.431949	0.6658	4.531028	<.0001*
		MACS 2	-2 (0)	0.45 (0.67)	0.23 (0.61)	<.0001*	40.7778	5.75862	<.0001*	-1.57720	0.1147	5.75841	<.0001*
		MACS 3	-2 (0)	0.08 (0.49)	0.23 (0.60)	<.0001*	24.9268	4.440220	<.0001*	1.262175	0.2069	4.440220	<.0001*
JTHFT (seconds)	**AH**	**MACS 1**	131.86 (102.64)	113.19 (58.85)	101.33 (52.19)	0.1844	3.3818	-1.17167	0.2413	-1.53925	0.1237	-2.57342	0.0101*
		MACS 2	279.37 (175.17)	250.12 (151.05)	261.63 (167.62)	0.0941	4.7273	-1.58440	0.1131	-1.42009	0.1556	-2.54678	0.0109*
		MACS 3	391.44 (198.23)	353.39 (192.79)	325.84 (171.26)	0.1160	4.3077	-1.48718	0.1370	-1.28205	0.1998	-3.12821	0.0018*
	NAH	**MACS 1**	41 (14.22)	37.43 (11.30)	33.67 (4.51)	0.0691	5.3455	-1.63114	0.1029	-1.81493	0.0695	-3.07892	0.0021*
		MACS 2	51.32 (13.96)	46.39 (11.39)	41.99 (9.65)	<.0001*	19.1818	-2.92234	0.0035*	-3.06318	0.0022*	-4.82362	<.0001*
		MACS 3	46.70 (8.41)	41.82 (8.36)	40.26 (7.48)	0.2390	2.8627	-2.02599	0.0428	-0.87179	0.3833	-2.87179	0.0041*
Box task (gram)		**MACS 1**	11617.86 (9864.61)	13542.86 (10326.89)	17707.14 (9927.77)	0.0002*	17.4717	1.540301	0.1235	2.642715	0.0082*	3.929064	<.0001*
		MACS 2	7840.91 (5666.83)	10295.46 (6467.24)	9418.18 (6528.3)	0.0093*	9.3611	3.20877	0.0013*	-0.43469	0.6638	2.34966	0.0188
		MACS 3	5461.54 (4815.17)	5346.15 (3460.40)	13384.62 (22356.17)	0.0289*	7.0909	0.102899	0.9180	2.696922	0.0070*	2.950736	0.0032*
Cup task (gram)	**AH**	**MACS 1**	1149.93 (819.63)	1035.71 (771.22)	1377.5 (993.79)	0.1873	3.3500	-0.80629	0.4201	2.23182	0.0256	1.56458	0.1177
		MACS 2	539.09 (923.97)	514.10 (888.81)	655.91 (1006.11)	0.9052	0.1993	-0.45176	0.6514	1.95722	0.0503	1.38015	0.1675
		MACS 3	283.08 (483.45)	215/38 (315.82)	283.46 (477.81)	0.9984	0.0032	-0.117123	0.9068	0.087823	0.9300	0.000000	1.0000
	NAH	**MACS 1**	4378.57 (1335.42)	4142.86 (1598.42)	4341.79 (1274.72)	0.7538	0.5652	-0.092009	0.9267	0.299110	0.7649	0.092161	0.9266
		MACS 2	2986.36 (1083.34)	3363.64 (1206.94)	3515.64 (1057.53)	0.2680	2.6333	1.662276	0.0965	0.731268	0.4646	2.120923	0.0339
		MACS 3	2769.23 (1091.93)	2461.54 (967.42)	2807.69 (902.28)	0.2453	2.8108	-0.90442	0.3658	1.49564	0.1347	0.48953	0.6245

WE: wrist extension; WEF: wrist extension with finger flexion; WFF: wrist flexion with finger flexion; Grip: grip strength; Pinch: pinch strength; COPM: Canadian Occupational Performance Measure; P: Performance; S: Satisfaction GAS: Goal Attainment Scale; JTHFT: Jebsen Taylor Hand Function Test; AH: Affected Hand; NAH: Non- Affected Hand; M1: first measurement; M2: second measurement; M3: third measurement;

Table 4:
Multivariate correlations – Baseline (spearman correlation coefficient)

		0.00 - 0.25		0.25 - 0.50		0.50 - 0.75		>.75	
Prim-Prim	**AH**					WE	WFF AH	WE	WEF AH
							Grip AH	Grip	Pinch AH
							Pinch AH		
						WEF	WFF AH		
							Grip AH		
							Pinch AH		
						WFF	Grip AH		
							Pinch AH		
	NAH			WE	Grip NAH				
				WEF	WFF NAH				
					Grip NAH				
					Pinch NAH				
				WFF	Pinch NAH				
				Grip	Pinch NAH				
Sec-Sec	**AH**	JTHFT	GAS	JTHFT	Box task			JTHFT	Cup task AH
				Cup task	Box task				
	NAH			Cup task	Box task			JTHFT	Cup task NAH
		Box task	GAS			COPM P	COPM S		
Prim-Sec	**AH**	WE	GAS	Grip	Abilhand	WE	JTHFT AH	JTHFT	Grip AH
		WEF	GAS	WE	Box task		Cup task AH		
				WEF	Box task	WEF	JTHFT AH	Cup	Grip AH
							Cup task AH		
						WFF	JTHFT AH		
							Cup task AH		
						Pinch	JTHFT AH		
							Box task		
							Cup task AH		
						Grip	Box task		
	NAH			WE	Box task	Grip	Cup task NAH		
				WEF	Box task				
				Grip	Box task				
					JTHFT NAH				
				WFF	Cup task NAH				
				Pinch NAH	Cup task NAH				

WE: wrist extension; WEF: wrist extension with finger flexion; WFF: wrist flexion with finger flexion; Grip: grip strength; Pinch: pinch strength; COPM: Canadian Occupational Performance Measure; COPM S: COPM Satisfaction; COPM P: COPM Performance; GAS: Goal Attainment Scale; JTHFT: Jebsen Taylor Hand Function Test; AH: Affected Hand; NAH: Non- Affected Hand; M1: first measurement; M2: second measurement; M3: third measurement; Prim: primary; Sec: Secondary;

9.2 Figures

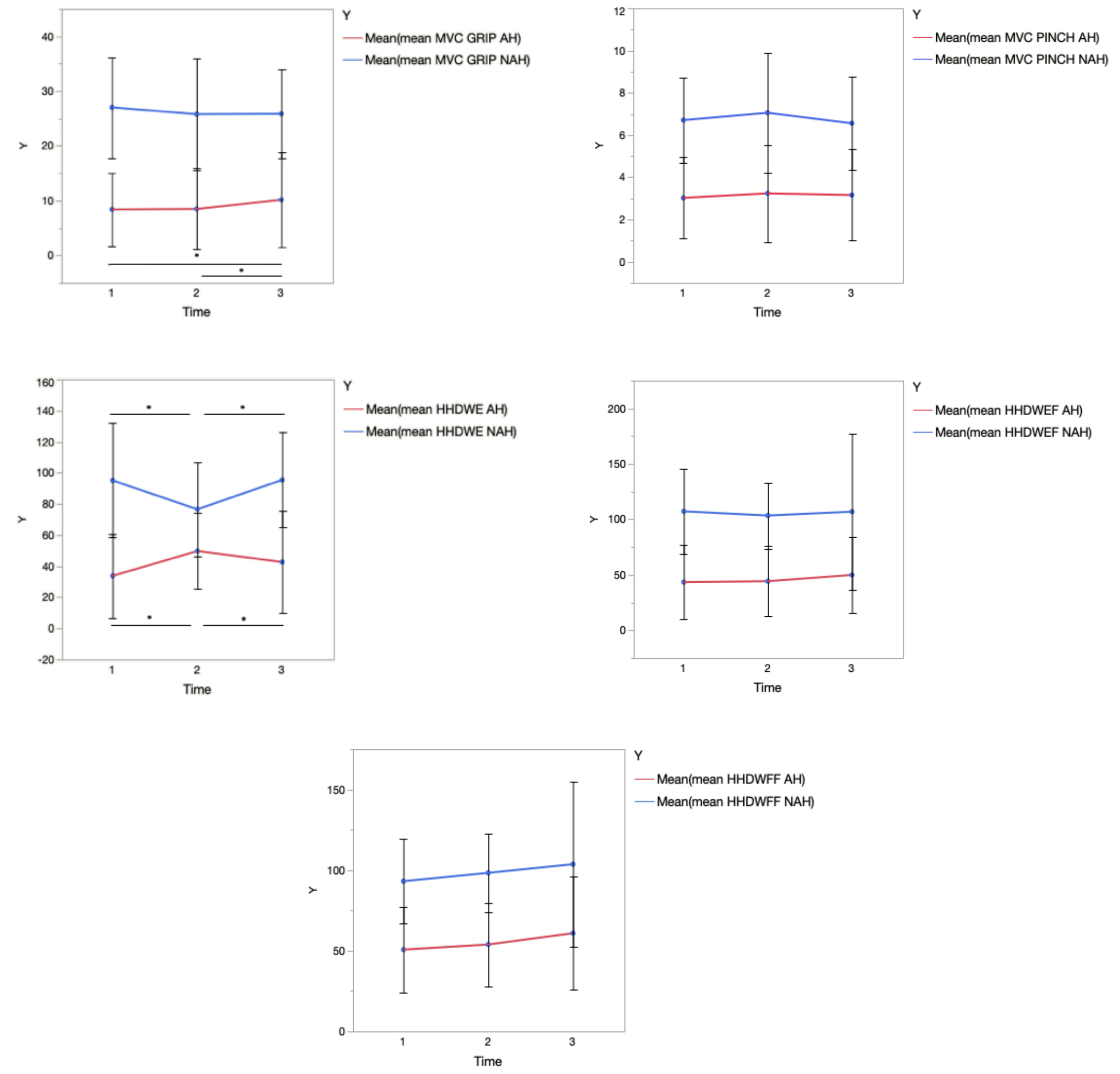

Figure 1: Primary outcome measures per time

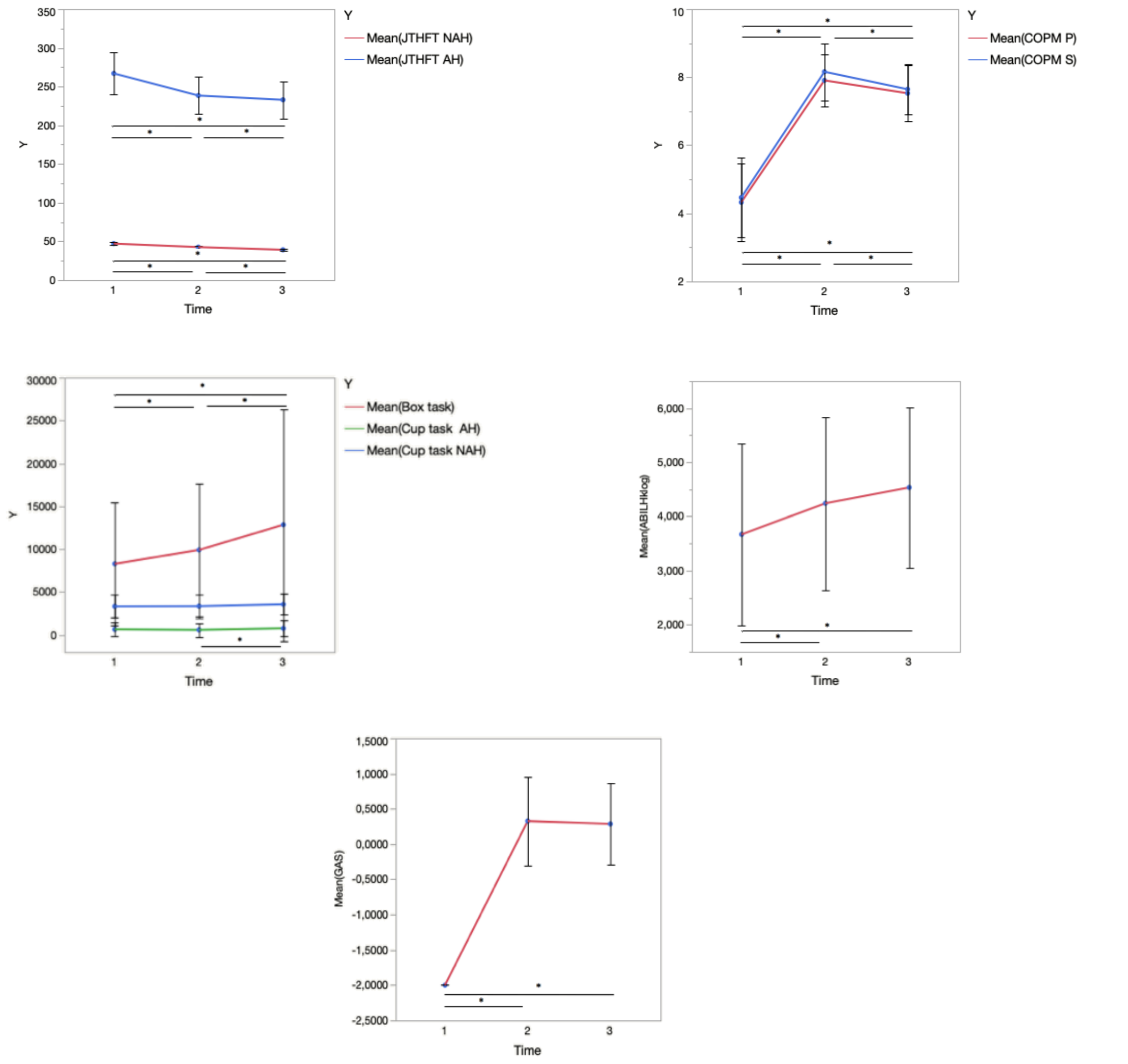

Figure 2: Secondary outcome measures per time

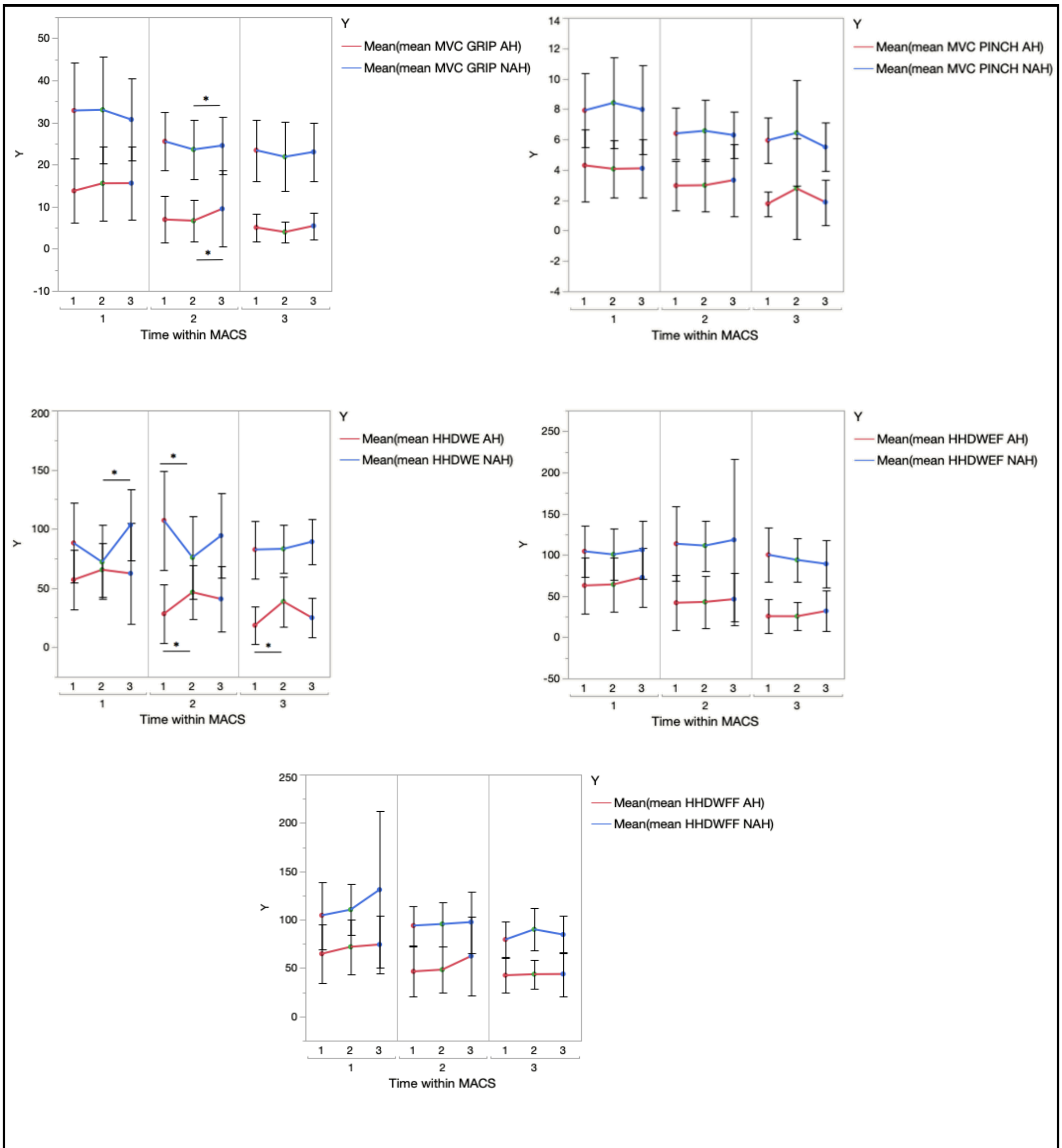

Figure 3: Primary outcome measures per MACS

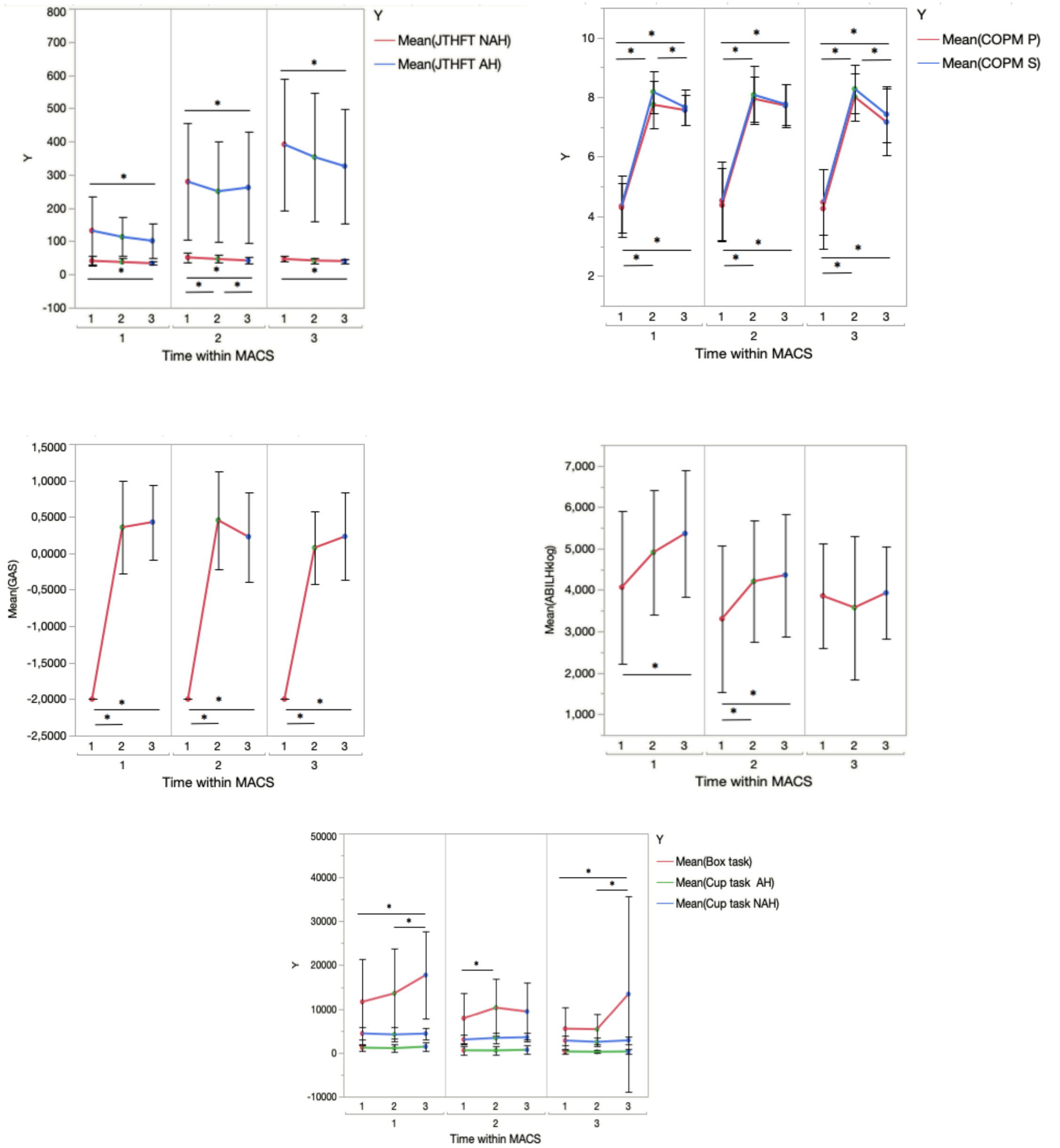

Figure 4: Secondary outcome measures per MACS

Informed consent

Verklaring van toestemming video-opnamen en gebruik van gegevens

Hiermee verklaard ondergetekende patiënt en /of vrijwilliger toestemming te hebben gegeven voor :

A. het maken van video-opnamen tijdens het BIMT kamp. De video-opnamen worden gebruikt voor:

1. didactische of informatieve doeleinden (voor paramedici en/of studenten)
2. PR ten behoeve van het BIMT kamp
3. plaatsing op de website van Adelante

Bij het gebruik van de video-opnamen wordt ervoor gezorgd dat persoonlijke gegevens niet zichtbaar zijn. De video-opnamen maken geen deel uit van het medisch dossier.

B. het gebruiken van de verkregen meetgegevens voor, tijdens en na het BIMT-kamp voor:

1. presentatie of informatieve doeleinden.
2. PR ten behoeve van het BIMT kamp
2. publicatie ten behoeve van het BIMT-kamp.

De meetgegevens worden anoniem gebruik. Er zijn geen gegevens te herleiden tot de patiënt zelf.

Hiermee verklaart ondergetekende projectleider de video-opnamen alleen te gebruiken voor bovengenoemde doeleinden waarvoor de patiënt toestemming heeft gegeven.

Plaats en datum: _______________, ___/____/20___

Ouders van de jongere of vrijwilliger

………….. ………….
(Handtekening)

………….. ……………..

(Naam in Blokletters)

Projectleider BIMT 2015

………….. ………….
(Handtekening)

………….. ……………..

(Naam in Blokletters)

Indien van toepassing
Wettelijk vertegenwoordiger:

………….. ………….
(Handtekening)

………….. ……………..
(Naam in Blokletters)

De jongere zelf (indien 12 jaar of ouder)

………….. ………….
(Handtekening)

………….. ……………..
(Naam in Blokletters)

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UHASSELT
KNOWLEDGE IN ACTION

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
09/10/2018	Bespreking verloop masterproef deel 2 Bespreking uitkomstmaten en protocol Afspraken maken	Promotor: Rameckers Eugene Student(e): Swennen Laurine Student(e): Boeckx Demi
7/12/2018	Bespreking resultaten en gedetailleerde informatie van andere kampen	Promotor: Rameckers Eugene Student(e): Swennen Laurine Student(e): Boeckx Demi
28/01/2019	Bespreking statistiek en algemene onduidelijkheden	Promotor: Rameckers Eugene Student(e): Swennen Laurine Student(e): Boeckx Demi
13/02/2019	Statistiek + resterende vragen	Promotor:Rameckers Eugene Student(e): Swennen Laurine Student(e): Boeckx Demi
03/04/2019	Overlopen tabellen, grafieken en algemene statistiek	Promotor: Rameckers Eugene Sudent (e): Swennen Laurine Student(e): Boeckx Demi
15/04/2019	Algemene bespreking van vragen en onduidelijkheden	Promotor: Rameckers Eugene Student(e): Swennen Laurine Student(e): Boeckx Demi
9/05/2019	Verzamelen handtekeningen en laatste feedback	Promotor: Rameckers Eugene Student(e): Swennen Laurine Student(e): Boeckx Demi

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Student(e): SWENNEN LAURINE .... **Datum:** 09-05-2019

Titel Masterproef: The effect of Bimanual Intensive Movement Therapy (BIMT) on muscle strength of the upper limb in children with unilateral cerebral palsy

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	○	○	○	○	○	●
Methodologische uitwerking	○	○	○	○	●	○
Data acquisitie	○	○	○	○	●	○
Data management	○	○	○	○	○	●
Dataverwerking/Statistiek	○	○	○	○	○	●
Rapportage	○	○	○	○	○	●

2) Niet-bindend advies: Student(e) krijgt toelating/~~geen toelating~~ (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke ~~stage~~/masterproef deel 2 mag wel/~~niet~~ (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke ~~stage~~/masterproef deel 2 mag wel/~~niet~~ (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)	Datum en handtekening promotor(en)	Datum en handtekening Co-promotor(en)
09-05-2019		

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Student(e): Demi Boeckx **Datum:** 9/05/'19

Titel Masterproef: The effect of Bimanual Intensive Movement Therapy (BIMT) on muscle strength of the upper limb in children with unilateral cerebral palsy.

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	O	O	O	O	O	●
Methodologische uitwerking	O	O	O	O	●	O
Data acquisitie	O	O	O	O	●	O
Data management	O	O	O	O	O	●
Dataverwerking/Statistiek	O	O	O	O	O	●
Rapportage	O	O	O	O	O	●

2) Niet-bindend advies: Student(e) krijgt toelating/~~geen toelating~~ (schrappen wat niet past) om bovenvermelde Wetenschappelijke ~~stage~~/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke ~~stage~~/masterproef deel 2 mag wel/~~niet~~ (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke ~~stage~~/masterproef deel 2 mag wel/~~niet~~ (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)	Datum en handtekening promotor(en)	Datum en handtekening Co-promotor(en)
9/05/'19	9/05/'19	