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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Test - Retest reliability of a protocol to measure dynamic fatigability in TD children

Pieter Hendrikx
Janne Vandereyt

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

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Prof. dr. Eugene RAMECKERS

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2018
2019

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Acknowledgement

First, we would like to thank Msc. Lieke Brauers to give us the opportunity to participate in her doctoral study and for her guidance and advice throughout the last two years. We also want to thank Prof. Dr. Eugene Rameckers for his critical remarks and advice. Then we want to thank all the participating children for their effort. At last we want to thank Adelante to give us the chance to be a part of the therapy camp for children with unilateral Cerebral Palsy last summer.

Research context

This master thesis is situated in the domain of neurological rehabilitation and paediatric rehabilitation. The first part consists of a systematic review on measurement of dynamic motor fatigability in patients with neurological disorders. The second part is a cross-sectional study to control the reliability of a newly developed protocol to measure dynamic motor fatigability in typically developing (TD) children.

This cross-sectional study is part of the master thesis in the second master year of rehabilitation sciences and physiotherapy at the University of Hasselt. In this study, we controlled the test-retest reliability of a newly developed protocol to measure dynamic fatigability in TD children. Normally, our aim was to test a protocol for CP children, but because there was no useful protocol available, we decided to develop a new one. This new protocol must be reliable in TD children and reference values need to be set up, before we could use the protocol in CP children.

This thesis was a duo master thesis. For the measurements, we worked together with Liesbeth Marai and Marie Merckx, who had a comparable subject. All four we did both the static and dynamic measurement of the children. They used the static data for their thesis, while we used the dynamic data. The writing was done separately.

The whole process was under supervision of Msc. Lieke Brauers. On a regular basis we received feedback from Prof. Dr. Eugene Rameckers.

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1. Abstract

BACKGROUND: No protocol to measure dynamic fatigability of the upper limb in children, and especially not in children with Cerebral Palsy has been established, although it is important to estimate the impact on daily activities.

AIM: To investigate the test-retest reliability of a newly developed protocol to measure dynamic fatigability in typically developing children.

METHODS: 27 typically developing children, aged between 7 and 18 years, participated in this study. They performed the test, consisting a handgrip and pinch grip measurement, with both hands twice. Intraclass correlations were calculated using a two-way random effects model for mean force and number of peaks in order to investigate the test-retest reliability of the protocol.

RESULTS: Moderate to excellent Intraclass Correlation Coefficient values were found for the mean force, with a moderate 95% confidence interval. For the number of peaks, the Intraclass Correlation Coefficient values are moderate, with a large 95% Confidence Interval. For the mean force the Smallest Detectable Difference percentages are high, those are lower for the number of peaks.

CONCLUSION: The protocol seems reliable when using mean force as an outcome measure. The protocol is easy to understand and fast. Future research with a larger sample is indicated to strengthen these results.

2. Introduction

Cerebral Palsy (CP) is a neurodevelopmental condition starting in early childhood and persisting through life. It is caused by a non-progressive disorder of the brain (Keith, Mackenzie, & Polani, 1959). Rosenbaum et al. (2007) define CP as "a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing foetal or infant brain." The motor disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour, by epilepsy, and by secondary musculoskeletal problems (Bax et al., 2005; Rosenbaum et al., 2007). These musculoskeletal problems include coexisting muscle spasticity and weakness (Rose & McGill, 2005), large deficits in voluntary muscle activation (Stackhouse, Binder-Macleod, & Lee, 2005) and increased antagonist coactivation, for example at the elbow joint (Brændvik & Roeleveld, 2012).

Another common problem in CP is motor fatigability (Hilberink et al., 2007). Motor fatigability has been defined as "an exercise-induced reduction in the ability of the neuromuscular system to produce force or power, which occurs during sustained and/or repeated voluntary contractions and can be measured as a decline in peak force, power, or a change in electromyogram (EMG) activity" (Bigland-Ritchie, Jones, Hosking, & Edwards, 1978; Enoka & Duchateau, 2008; Kluger, Krupp, & Enoka, 2013). Although this definition is not consistently used, this definition is covering all relevant aspects concerning motor fatigability.

Two types of motor fatigability can be distinguished: static and dynamic. Static fatigability can be measured during static contractions where the limb exerts a force without a change in joint angle. Dynamic fatigability, in contrast can be measured during dynamic activities (Severijns et al., 2017).

Motor fatigability interferes with the performance of several activities of daily living. It also influences the quality of life (QoL). A major goal in children with unilateral CP is to increase independence and participation. The functionality of the upper limb is important to achieve this. The upper limb is used in most activities of daily living, such as eating, drinking, washing and writing (Keller & Van Hedel, 2017). In more severe cases of CP, the upper limb is also needed to walk with a walker or driving a wheelchair. This makes proper assessment all the more useful in objectifying and evaluating motor fatigability.

More and more evidence on high intensity strength training for improving force production, walking velocity and gross motor function is accumulating (Stackhouse et al., 2005). In order to do this, reference values and reliable measurements of dynamic fatigability need to be established.

However, little is known about the objective measurement of motor fatigability in children with CP. Different methods are used to evaluate dynamic physical activity and motor fatigability: Russchen et al. (2014) used questionnaires to assess motor fatigability and accelerometry to measure daily physical activity, while Balemans, van Wely, Becher, and Dallmeijer (2015) used an ankle worn activity monitor and the Paediatric Quality of Life (PedsQL) Multidimensional Fatigue Scale to measure respectively physical activity and motor fatigability. However, these scales and questionnaires are rather subjective, which give an impression about the feeling of fatigability the patient experienced. No standard protocol exists to objectively measure dynamic fatigability in children with CP. Also, in comparable populations there is no golden standard available. In neurological patients dynamic fatigability is measured mostly by surface EMG or an arm ergometer, but different researchers use different protocols. There are no reference values for any protocol (Hendrikx & Vandereyt, unpublished data, 2018). According to Patikas, Williams, and Ratel (2018) near-infrared spectroscopy (NIRS) measurement is the only method used in children to measure motor fatigability. There are no standard protocol or reference values available for this method or any other method.

This study is conducted on typically developing (TD) children in order to examine the test-retest reliability of a newly developed fatigability protocol. The following research question is formulated: what is the test-retest reliability of a newly developed protocol to measure dynamic fatigability of the upper limb in TD children?

3. Methods

3.1 Research design

This study was a cross-sectional study. The participants performed a newly developed fatigability protocol with the E-LINK H500 Handkit (Biometrics Ltd.) The E-LINK software, version 15, was used to display the data. This study is approved by the Medical Ethics Committee of the university of Hasselt. (CME2018-069).

3.2 Participants

3.2.1 Patient recruitment

Participants are recruited in local schools, sport clubs and youth organisations. Flyers with information about the study were distributed (Appendix 2). Parents or guardians of interested children sent an e-mail when interested. Thereafter the following data of each participant were collected via a phone call: date of birth, dominant hand, preferred language and former injuries of the upper limb (Appendix 3).

Informed consent was given and signed by the parents (Appendix 4).

3.2.2 Inclusion criteria

The following inclusion criteria were set : (1) age between 7 and 18 years old, (2) Dutch speaking, (3) ability to understand and perform the task, (4) no treatment for problems in the use of the upper limbs in the past and (5) no injuries of the upper limbs in the last six months.

3.2.3 Exclusion criteria

Children were excluded if they have a known developmental delay or any neurological, neuromuscular or other disorders of the upper limb that could affect muscle force.

3.3 Measurement

3.3.1 Fatigability protocol

Each participant was tested twice by the same researcher with at least 48 hours and maximum 7 days in between the two test moments.

The child sat on a chair with his/her feet flat on the ground. The elbow of the tested arm was flexed in 90° and was not supported.

The test itself consisted of four parts: a dynamic grip and pinch fatigability protocol for both the dominant and non-dominant hand. For the dynamic measurement the child squeezed the hand grip dynamometer as hard and as fast as possible for 30 seconds. After this measurement the same thing was done with the pinch meter. This key pinch or lateral pinch can be described as a grasp pattern in which the object is held between the thumb pads and the radial side of the index finger.

The therapist stimulated him or her verbally to pinch or to squeeze as hard and as fast as they possibly could. The participant started with his or her dominant hand, followed by the other side.

3.3.2 Measurement instruments

Dynamic fatigability was objectively measured in TD children using the E-LINK H500 Handkit (Biometrics Ltd.). If the protocol proved to be reliable, reference values would be generated. In a subsequent study the same measurements will be done on children with CP to compare the results.

The handkit, consisting of a hand grip dynamometer and pinch meter (figure 1), was used to measure hand and pinch grip force with an accuracy of 0,1 Newton (N). A DataLITE wireless sensor (Biometrics Ltd.) connected the meters to a standard laptop with the associated E-LINK software, version 15.

Figure 1: **E-LINK dynamometer and pinch grip meter (Source: Website Biometrics Ltd.)**

3.4 Data-analysis

For the statistical analysis, data were divided in three time zones: 0-10 seconds, 10-20 seconds and 20-30 seconds. We assumed the maximum strength was reached in the first 10 seconds, from 10-20 seconds the strength output will decrease and the lowest values will be given from 20-30 seconds due to muscle fatigability. For each zone, mean force, maximum force and the number of peaks were retained. For the statistical analysis SPSS, version 25 (SPSS Inc., Chicago, IL, USA) and Excel (Office 365) was used. The assessors were blinded when analysing the data.

To investigate the test-retest reliability, intraclass correlation coefficients (ICC) two-way random-effects model with absolute agreement were used. The values were calculated by means of the mean force values and number of peaks. This was done for four conditions: dynamometer dominant hand (DD), dynamometer non-dominant hand (DND), pinch meter dominant hand (PD) and pinch meter non dominant hand (PND). A 95% confidence interval (CI) of the ICC values was calculated as well.

Along with the ICC and their accompanying 95%CI, the standard error of measurement (SEM) and the smallest detectable difference (SDD) were calculated. The SEM was calculated as 'Standard deviation /√(1-ICC)' and the SDD was calculated as '1.96*SEM*√(2)'. The SEM determined the variability between the measurements while the SDD determined the value when a clinically important change can be detected (de Vet, Terwee, Knol, & Bouter, 2006; Keszei, Novak, & Streiner, 2010; Souza, Alexandre, & Guirardello, 2017; Zuidam, Selles, Stam, & Hovius, 2008). The SDD was also presented as a percentage of mean force and mean number of peaks.

After checking the data for normal distribution, Bland-Altman plots were made to show the agreement between the measurements. To evaluate the level of agreement between the test and retest, limits of agreement (LOA) were used along with the SEM and the SDD. Outliers, measurements that were extremely different from the rest of the dataset, were detected and reported.

Heteroscedasticity was checked based on visual inspection of the Bland-Altman plots. Heteroscedastic distribution of the data was assumed if the amount of error increased as the measured values increased.

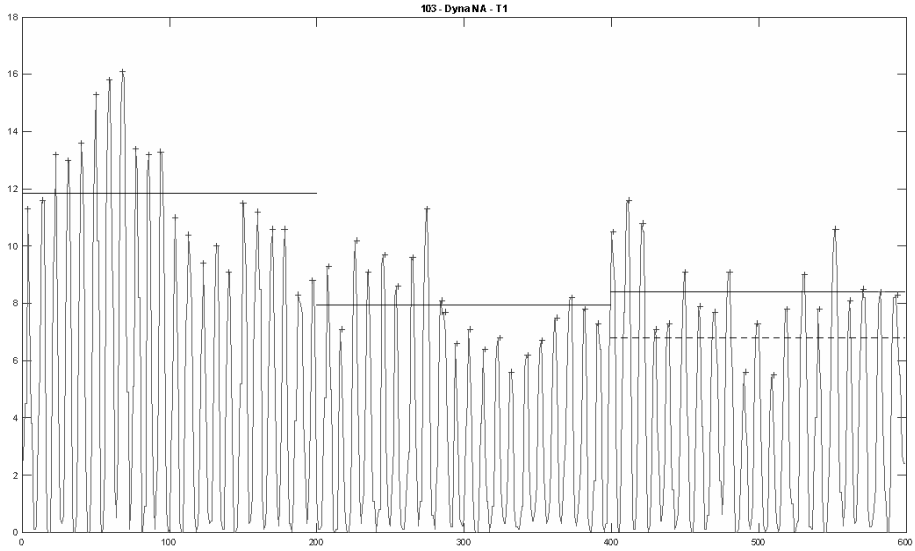


Figure 2: **Example of a graphical presentation of the data.**

4. Results

4.1 Population characteristics

From the 41 participants that were tested only 27 were useful for analyses. 14 participants dropped out: illness, incorrect performance of the protocol or problems with the wireless transmission of data between the E-link and the laptop in one of the two measurements were the main reasons. None of the drop outs was due to the protocol.

The data of 27 TD children were used in this study. The mean age of the population group at the time of the first testing was 10 years and 8 months with a standard deviation of 2 years and 7 months. 25.9% of the population were boys. The right hand was dominant in 81.5% of the population.

The subject characteristics are displayed in table 1.

Table 1: Subject characteristics

Number of children	**27**
Mean age ±SD	10 years 8 months ±2 years 7 months
Gender	
Male	7 (25.9%)
Female	20 (74.1%)
Dominant hand	
Right	22 (81.5%)
Left	5 (18.5%)

SD: Standard Deviation

4.2 Mean force

For the dynamometer ICC values ranged from 0.788 to 0.918, the SEM ranged from 1.014 to 1.882 and the SDD ranged from 35.95% to 70.20%.

For the pinch meter ICC values ranged from 0.722 to 0.812, the SEM ranged from 0.425 to 0.556 and the SDD ranged from 61.01% to 94.61%.

The detailed data are displayed in table 2.

4.3 Number of peaks

For the dynamometer ICC values ranged from 0.344 to 0.658, the SEM ranged from 2.889 to 5.753 and the SDD ranged from 34.70% to 50.73%.

For the pinch meter ICC values ranged from 0.712 to 0.791, the SEM ranged from 2.915 to 4.311 and the SDD ranged from 30.30% to 39.84%.

The detailed data are displayed in table 3.

Table 2: Outcome measurements mean force

Measure	ICC	95%CI	SEM	SDD	SDD(%Mean)	meanDIFF
DD 0-10 Fmean	0.918	0.810-0.963	1.083	3.002	35.95	0,8051
DD 10-20 Fmean	0.893	0.764-0.951	1.014	2.812	47.27	-0,0308
DD 20-30 Fmean	0.813	0.586-0.815	1.211	3.358	61.14	-0,1278
DND 0-10 Fmean	0.849	0.660-0.932	1.882	5.215	54.40	1,3418
DND 10-20 Fmean	0.799	0.529-0.911	1.786	4.950	70.20	1,4898
DND 20-30 Fmean	0.788	0.540-0.903	1.510	4.182	70.13	0,8996
PD 0-10 Fmean	0.786	0.506-0.905	0.425	1.177	61.01	0,3471
PD 10-20 Fmean	0.756	0.439-0.981	0.467	1.294	79.80	0,3885
PD 20-30 Fmean	0.791	0.536-0.905	0.417	1.157	73.62	0,4098
PND 0-10 Fmean	0.812	0.591-0.920	0.501	1.388	65.42	0,3796
PND 10-20 Fmean	0.784	0.533-0.901	0.512	1.419	80.16	0,2580
PND 20-30 Fmean	0.722	0.390-0.873	0.556	1.541	94.61	0,1348

Fmean: mean force; DD: dynamometer dominand hand; DND: dynamometer non-dominant hand; PD: pinchmeter dominant hand; PND: pinchmeter non-dominant hand; ICC: intercorrelation coëfficiënt; CI: confidence interval; SEM: standard error of measurement; SDD: smallest detectable difference; meanDIFF: mean differences

Table 3: Outcome measurements number of peaks

Measure	ICC	95%CI	SEM	SDD	SDD(%mean)	meanDIFF
DD 0-10 #peaks	0.617	0.051-0.837	3.630	10.062	34.70	-4,0370
DD 10-20 #peaks	0.593	0.093-0.816	3.481	9.649	38.60	-3,3333
DD 20-30 #peaks	0.658	0.252-0.844	2.889	8.001	34.82	-2,3333
DND 0-10 #peaks	0.344	0.218-0.666	5.753	15.946	54.99	-5,9630
DND 10-20 #peaks	0.433	0.132-0.738	4.501	12.494	46.28	-4,8889
DND 20-30 #peaks	0.485	0.049-0.757	4.576	12.684	50.73	-4,0741
PD 0-10 #peaks	0.776	0.514-0.898	3.170	8.787	30.30	-2,0000
PD 10-20 #peaks	0.765	0.409-0.892	3.151	8.734	32.25	-1,2593
PD 20-30 #peaks	0.791	0.536-0.905	2.915	8.080	32.32	-2,0741
PND 0-10 #peaks	0.755	0.255-0.898	4.157	11.522	36.01	-4,2593
PND 10-20 #peaks	0.712	0.368-0.869	4.311	11.951	39.84	-3,2222
PND 20-30 #peaks	0.740	0.437-0.881	4.001	11.090	38.24	-1,5185

#Peaks: number of peaks; DD: dynamometer dominand hand; DND: dynamometer non-dominant hand; PD: pinchmeter dominant hand; PND: pinchmeter non-dominant hand; ICC: intercorrelation coëfficiënt; CI: confidence interval; SEM: standard error of measurement; SDD: smallest detectable difference; meanDIFF: mean differences

4.4 Heteroscedasticity examination

In the Bland-Altman plots at least one outlier was noticed in each plot, with a mean of 1.67 and a maximum of three outliers. In total, 40 outliers were noticed spread over 24 plots. We could assume there is a good agreement between the two measurements.

The plots can be found in appendix 5.

5. Discussion

This study is a cross sectional study with the aim to investigate the test-retest reliability of the E-Link hand grip dynamometer and pinch meter for TD children. ICC, 95% CI, SEM, SDD, mean DIFF, LOA's and Bland-Altmann plots are calculated and used in the statistical analyses.

Mean force ICC showed moderate to excellent reliability with values ranging from 0.72 to 0.92. The 95%CI's are moderately large (table 2). The number of peaks showed moderate reliability with values ranging from 0.34 to 0.79 (Koo & Li, 2016). Here, the 95%CI's are very large (table 3) what makes a rather poor reliability. These results are not according to the findings of Zuidam et al. (2008). They found high ICC values (>0.90) for hand strength measurements in children. A possible explanation is that they examined thumb palmar abduction, thumb opposition, flexion of the metacarpal-phalangeal joint, index finger abduction, and little finger abduction while this study focussed on a general hand grip and key pinch force and number of peaks. Another difference is the time interval between the test and the retest: 27 days in comparison to maximum 7 days in this study. Probably there is a learning effect in this study.

Since this is the first protocol to assess dynamic fatigability of the upper limb in TD children no comparable studies can be found. More is known about strength in isometric maximal contractions. Hogrel (2015) for example, found values for the test-retest reliability of the Myogrip and Jamar devices during 2 maximal grip strength measurements. The retest was performed at least one day and maximum 3 months after the first measurement. They found an excellent ICC value (0.967 for Myogrip; 0.947 for Jamar) for a population with ages from 4 to 80 years old. One might assume the older population performed both tests with less variation than this younger population.

Klingels et al. (2010) found values for the test-retest reliability of the Jamar device in 23 CP children. The device was used to determine grip strength. The retest was performed two weeks after the first measurement. ICC values were also excellent in this study (0.96; 95%CI:0.90-0.98). It is not clear if the excellent values are because of the protocol or because of the CP population.

Another difference lies in the fact that in all these studies the participants had to perform an isometric strength contraction. In contrast to this study, where a dynamic fatigability protocol is performed by the participants. This could account for the lower reliability values.

Next to ICC values, SEM and SDD values are calculated. Only a small amount of measurement error in detecting real change over time, is useful for clinical practice (Schreuders et al., 2000).

When looking at the SDD's expressed as a percentage of mean between the two measurements, relatively large numbers were found. Especially when looking at the mean force of both the dynamometer (mean SDD of 65.63%) and the pinch meter (mean SDD of 77.27%). This means a big improvement in muscle force has to be made in order to be clinically significant for the dynamometer as well as for the pinch meter in both dominant and non-dominant hand. Lower SDD (%mean) values are found when looking at the number of peaks: 43.36% for the dynamometer and 34.82% for the pinch meter. This means the increase in number of peaks needs to be proportionally lower to be clinically significant in comparison to the mean force. Nevertheless, these values are large.

No relevant articles who examined SEM and SDD were found to compare our results with. Dekkers, Rameckers, Smeets, and Janssen-Potten (2014) reviewed upper strength measurements for CP children. None of the four included articles that looked at test-retest reliability calculated SEM or SDD values.

A large limitation of this study is the fact that 41 participants were tested while only the data of 27 participants are used in the data analysis. This makes a dropout rate of 36.59%.

A few reasons can be named for this. There were some technical problems with the wireless transmission of data between the E-link and the laptop in five cases. This made the data unusable. Other participants were only measured once because of illness. A third reason was that some participants did not perform the protocol correctly and due to the inexperience of the researchers and the time schedule, these measurements were not repeated in the appropriate way. This makes up for the small number of participants (N=27).

A second limitation of the study is that all measurements are done in the same centre. So due to the small sample size and the lack of multicentricity, these results cannot be generalized on a larger population (for example European schoolchildren). However, the smaller population of Flemish schoolchildren is more appropriate to compare these results with.

6. Conclusion

The protocol has proven to be reliable to measure mean force during a dynamic fatigability protocol. Care must be taken when using the number of peaks. Nevertheless, it is easier to detect clinically significant changes when looking at the number of peaks. This makes it interesting to consider both these methods in the clinical practice. Furthermore, the hand grip dynamometer and pinch meter are fast, easy to understand and frequently available as measurement instruments.

Future research on this topic should focus on a relationship with subjective fatigability on a larger number of participants.

7. Reference list

Balemans, A. C., van Wely, L., Becher, J. G., & Dallmeijer, A. J. (2015). Longitudinal relationship among physical fitness, walking-related physical activity, and fatigue in children with cerebral palsy. *Physical therapy, 95*(7), 996-1005.

Bax, M., Goldstein, M., Rosenbaum, P., Leviton, A., Paneth, N., Dan, B., . . . Damiano, D. (2005). Proposed definition and classification of cerebral palsy, April 2005. *Developmental medicine and child neurology, 47*(8), 571-576.

Bigland-Ritchie, B., Jones, D., Hosking, G., & Edwards, R. (1978). Central and peripheral fatigue in sustained maximum voluntary contractions of human quadriceps muscle. *Clinical Science, 54*(6), 609-614.

Brændvik, S. M., & Roeleveld, K. (2012). The role of co-activation in strength and force modulation in the elbow of children with unilateral cerebral palsy. *Journal of Electromyography and Kinesiology, 22*(1), 137-144.

de Vet, H. C., Terwee, C. B., Knol, D. L., & Bouter, L. M. (2006). When to use agreement versus reliability measures. *Journal of clinical epidemiology, 59*(10), 1033-1039.

Dekkers, K. J., Rameckers, E. A., Smeets, R. J., & Janssen-Potten, Y. J. (2014). Upper extremity strength measurement for children with cerebral palsy: a systematic review of available instruments. *Physical therapy, 94*(5), 609-622.

Enoka, R. M., & Duchateau, J. (2008). Muscle fatigue: what, why and how it influences muscle function. *J Physiol, 586*(1), 11-23. doi:10.1113/jphysiol.2007.139477

Hendrix, P., & Vandereyt, J. (2018). Measurement instruments for dynamic fatigability in neurological patients. *(non published data)*.

Hilberink, S. R., Roebroeck, M. E., Nieuwstraten, W., Jalink, L., Verheijden, J., & Stam, H. J. (2007). Health issues in young adults with cerebral palsy: towards a life-span perspective. *Journal of Rehabilitation Medicine, 39*(8), 605-611.

Hogrel, J.-Y. (2015). Grip strength measured by high precision dynamometry in healthy subjects from 5 to 80 years. *BMC musculoskeletal disorders, 16*(1), 139.

Keith, R. M., Mackenzie, I., & Polani, P. (1959). Definition of cerebral palsy. *Developmental Medicine & Child Neurology, 1*(5), 23-23.

Keller, J. W., & Van Hedel, H. J. (2017). Weight-supported training of the upper extremity in children with cerebral palsy: a motor learning study. *Journal of neuroengineering and rehabilitation, 14*(1), 87.

Keszei, A. P., Novak, M., & Streiner, D. L. (2010). Introduction to health measurement scales. *Journal of psychosomatic research, 68*(4), 319-323.

Klingels, K., De Cock, P., Molenaers, G., Desloovere, K., Huenaerts, C., Jaspers, E., & Feys, H. (2010). Upper limb motor and sensory impairments in children with hemiplegic cerebral palsy. Can they be measured reliably? *Disability and Rehabilitation, 32*(5), 409-416.

Kluger, B. M., Krupp, L. B., & Enoka, R. M. (2013). Fatigue and fatigability in neurologic illnesses: proposal for a unified taxonomy. *Neurology, 80*(4), 409-416.

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of chiropractic medicine, 15*(2), 155-163.

Patikas, D. A., Williams, C. A., & Ratel, S. (2018). Exercise-induced fatigue in young people: advances and future perspectives. *European journal of applied physiology, 118*(5), 899-910.

Rose, J., & McGill, K. C. (2005). Neuromuscular activation and motor-unit firing characteristics in cerebral palsy. *Developmental medicine and child neurology, 47*(5), 329-336.

Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., Bax, M., Damiano, D., . . . Jacobsson, B. (2007). A report: the definition and classification of cerebral palsy April 2006. *Developmental medicine and child neurology. Supplement, 109*, 8-14.

Russchen, H. A., Slaman, J., Stam, H. J., van Markus-Doornbosch, F., van den Berg-Emons, R. J., & Roebroeck, M. E. (2014). Focus on fatigue amongst young adults with spastic cerebral palsy. *Journal of neuroengineering and rehabilitation, 11*(1), 161.

Schreuders, T., Roebroeck, M., van der Kar, T. J., Soeters, J., Hovius, S., & Stam, H. (2000). Strength of the intrinsic muscles of the hand measured with a hand-held dynamometer: reliability in patients with ulnar and median nerve paralysis. *The Journal of Hand Surgery: British & European Volume, 25*(6), 560-565.

Severijns, D., Zijdewind, I., Dalgas, U., Lamers, I., Lismont, C., & Feys, P. (2017). The assessment of motor fatigability in persons with multiple sclerosis: a systematic review. *Neurorehabilitation and Neural Repair, 31*(5), 413-431.

Souza, A. C. d., Alexandre, N. M. C., & Guirardello, E. d. B. (2017). Psychometric properties in instruments evaluation of reliability and validity. *Epidemiologia e Serviços de Saúde, 26*(3), 649-659.

Stackhouse, S. K., Binder-Macleod, S. A., & Lee, S. C. (2005). Voluntary muscle activation, contractile properties, and fatigability in children with and without cerebral palsy. *Muscle & Nerve: Official Journal of the American Association of Electrodiagnostic Medicine, 31*(5), 594-601.

Zuidam, J. M., Selles, R. W., Stam, H. J., & Hovius, S. E. (2008). Age-specific reliability of two grip-strength dynamometers when used by children. *JBJS, 90*(5), 1053-1059.

8. Appendices

Appendix 1: List with abbreviations

Abbreviation	Meaning
CP	Cerebral Palsy
DD	Dynamometer dominant hand
DND	Dynamometer non dominant hand
EMG	Electromyogram
ICC	Intraclass correlation coefficients
LOA	Level of agreement
Mean Diff	Mean difference
NIRS	Near Infrared Spectroscopy
PD	Pinch meter dominant hand
PEDQL	Paediatric Quality of Life
PND	Pinch meter non dominant han
QoL	Quality of Life
SDD	Smallest detectable difference
SEM	Standard error of measurements
TD	Typically developing

Appendix 2: Information flyer

Hoe snel zijn jouw spieren moe?

Kom ons helpen!

WAAROM?

Om mee te helpen aan een onderzoek naar vermoeidheid in de handen bij kinderen.

VOOR WIE?

- Kinderen en jongeren tussen 6 en 18 jaar
- Geen problemen in de armen of handen
- Nederlands sprekend

WAT?

- Zo hard mogelijk knijper
- Zolang mogelijk knijpen
- Vaak na elkaar knijpen

Elk testmoment duurt maximaal 30 minuten. Er zijn twee testmomenten.

WAAR?

Meestal op school, maar dat kan ook elders.

UHASSELT
KNOWLEDGE IN ACTION

INTERESSE OF VRAGEN?

Neem dan contact op met:
Lieke Brauers
lieke.brauers@uhasselt.be

Appendix 3: Informed consent

INFORMATIEBRIEF EN TOESTEMMINGSFORMULIER OUDERS

STATISCHE EN DYNAMISCHE MOTORISCHE VERMOEIBAARHEID IN HET BOVENSTE LIDMAAT BIJ NORMAAL ONTWIKKELENDE KINDEREN EN JONGEREN.

Beste ouders en kinderen,

Wij vragen jullie om mee te doen met ons wetenschappelijk onderzoek. Hieronder vinden jullie meer informatie over wat we willen onderzoeken.

Het onderzoek

Er zijn kinderen die één of beide armen en handen niet zo goed kunt gebruiken, omdat ze een probleem hebben in hun hersenen of in hun spieren. Voor deze kinderen willen we goede methoden ontwikkelen om deze problemen te onderzoeken. Bij dit onderzoek gaan we kijken naar een meting voor vermoeibaarheid tijdens het knijpen. Honderd kinderen en jongeren die normaal ontwikkelen mogen meedoen aan dit onderzoek en wij willen uw toelating vragen om uw kind te laten meedoen

De metingen

Uw kind gaat twee keer dezelfde meting doen op twee verschillende dagen binnen een week. De metingen duren ongeveer 30 minuten per keer. Als eerste wordt gekeken hoe sterk uw kind is. Dit wordt gedaan door te knijpen met de hele hand of enkel met de vingers. Daarna gaan we kijken hoe snel uw kinds hand vermoeid raakt op twee verschillende manieren: door lang te blijven knijpen en door heel vaak en snel te knijpen. De testen zullen worden afgenomen door studenten van de Masteropleiding Revalidatiewetenschappen en Kinesitherapie van de UHasselt onder begeleiding van onderzoeker Lieke Brauers.

Als uw kind tijdens het onderzoek toch niet meer mee wilt doen, mag hij of zij altijd stoppen zonder aan te geven waarom. Ook als uw kind weigert de meting uit te voeren, zal dit gezien worden als teken dat hij of zij zich niet prettig voelt en zal de meting gestopt worden.

Als jullie samen besluiten om mee te doen met dit onderzoek, zullen we u opbellen om een afspraak te maken. De afspraak voor het onderzoek wordt gepland op een tijdstip dat uw kind al op school of in de jeugdbeweging is, zodat u niet extra hoeft te komen.

Nadenken

Natuurlijk krijgen jullie de tijd om na te denken of je aan dit onderzoek mee wilt doen. Als er vragen zijn horen wij dat uiteraard graag. Als jullie besluiten mee te doen dan kunt u dit aan ons doorgeven. Jullie hoeven natuurlijk niet mee te doen. De reden waarom u ervan af ziet hoeft ook niet met ons gedeeld te worden (dat mag natuurlijk wel). Er zullen geen resultaten van het onderzoek met u worden gedeeld.

Met vriendelijke groet,

Katrijn Klingels en Lieke Brauers,
Martelarenlaan 42,
3500 Hasselt, België
t. 011/26 9321 (ma-di-wo), 0031 43 388 2168 (do-vr)

E-Mail: lieke.brauers@uhasselt.be

TOESTEMMINGSVERKLARING

Onderzoek naar motorische vermoeibaarheid bij normaal ontwikkelende kinderen en jongeren.

Ik ben naar tevredenheid over het onderzoek geïnformeerd. Ik heb de schriftelijke informatie goed gelezen.

- Wij zijn in de gelegenheid gesteld om vragen over het onderzoek te stellen. Onze vragen zijn naar tevredenheid beantwoord.
- De resultaten van dit onderzoek zullen vertrouwelijk en anoniem behandeld worden.
- De onderzoeksgegevens mogen tot maximaal 15 jaar na afloop van dit onderzoek bewaard worden.
- We hebben goed over deelname aan het onderzoek kunnen nadenken.
- Wij en ons kind hebben het recht om onze toestemming op ieder moment weer in te trekken zonder dat we daarvoor een reden hoeven op te geven en zonder dat dit nadelige effecten zal hebben op de verdere zorg en behandeling van ons kind.
- Indien wij of ons kind ons op enig moment verzet tegen het onderzoek, zal dit gezien worden als intrekking van de toestemming en zal de meting op dat moment worden gestopt.

Wij stemmen toe met deelname van ons kind aan het onderzoek en geven hierbij tevens toestemming voor anoniem gebruik van de onderzoeksgegevens voor wetenschappelijk publicaties.

In de toekomst is het mogelijk dat we jullie opnieuw benaderen voor mogelijk vervolgonderzoek. Hiervoor zal altijd opnieuw toestemming gevraagd worden.

Naam kind: _____

Naam wettelijke vertegenwoordiger: _____

Geboortedatum: _____

Handtekening: _____

Datum: _____

VOOR DE ARTS / ONDERZOEKER:

Ondergetekende verklaart dat de hierboven genoemde personen zowel schriftelijk als mondeling over het bovenvermelde onderzoek geïnformeerd zijn. Hij/zij verklaart tevens dat een voortijdige beëindiging van de deelname door bovengenoemde persoon, van geen enkele invloed zal zijn op de zorg die hem of haar toekomt.

Ondergetekende verbindt zich dat het onderzoek wordt uitgevoerd volgens de in de informatiebrief gegeven informatie en zal zorgen, dat de privacy van de proefpersoon wordt gewaarborgd.

Naam: _____

Functie: _____

Handtekening: _____

Datum : _____

Appendix 4: Inclusion questionnaire

FORMULIER VOOR HET INCLUDEREN VAN NORMAAL ONTWIKKELENDE KINDEREN

UHASSELT
KNOWLEDGE IN ACTION

Naam: _____

Geboortedatum: _____

Dominante hand: _____

Moedertaal: _____

Ben je in het verleden behandeld voor problemen in het gebruik van je arm/hand? JA / NEE

Als ja, waarvoor? _____

Ben je de afgelopen 6 maanden gewond geraakt aan je arm/hand? JA / NEE

Als ja, wat had je voor verwonding? _____

Als je verklaart dat wat je hierboven hebt ingevuld klopt, verzoeken wij je om hieronder nogmaals je naam, datum en handtekening in te vullen.

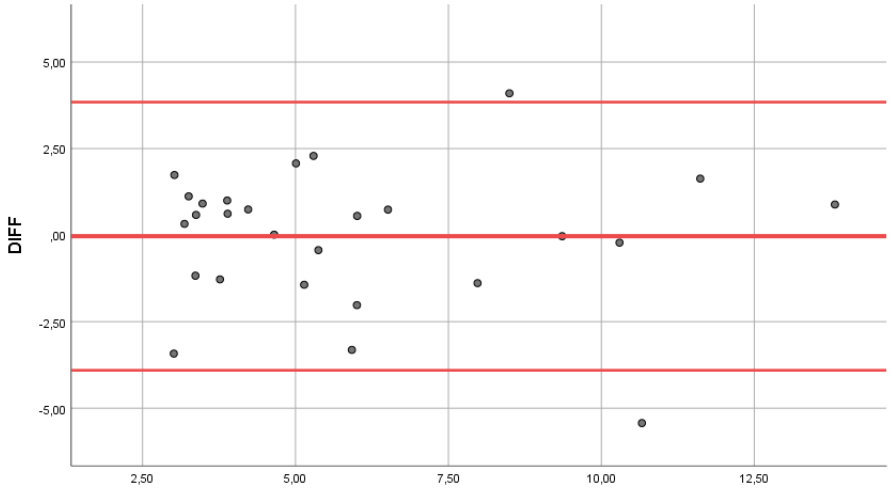
Naam: _____

Datum: _____

Handtekening:

Appendix 5: Bland-Altman plots

The middle line shows the mean difference between the two measurements, the limits of agreement are showed by the upper and lower lines. The mean of both measurements of all subjects are displayed on the X-axis. The difference between both measurements of all subjects are displayed on the Y-axis.



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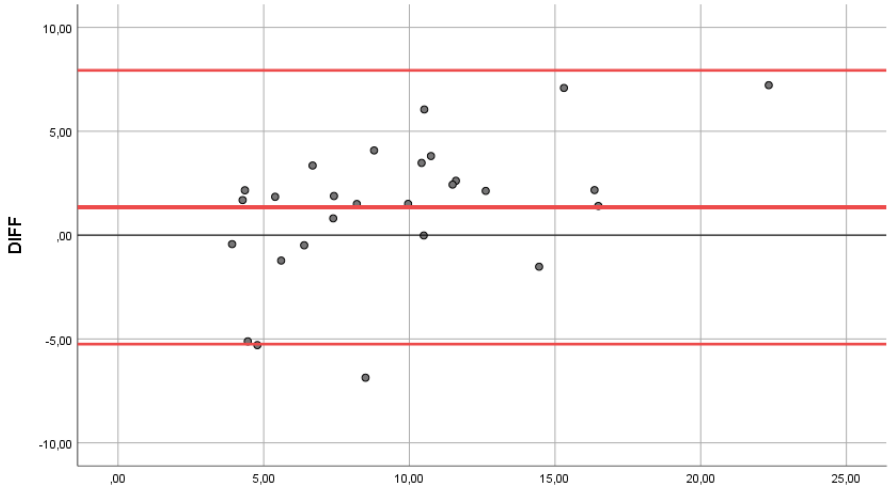
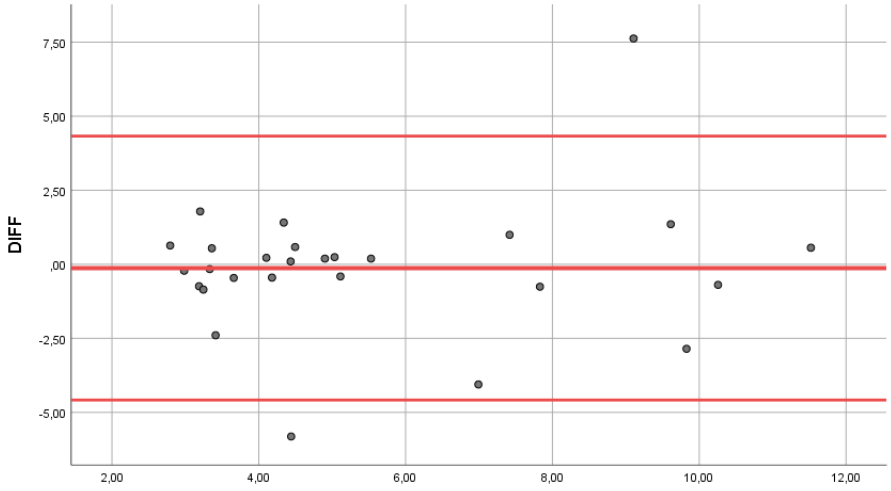
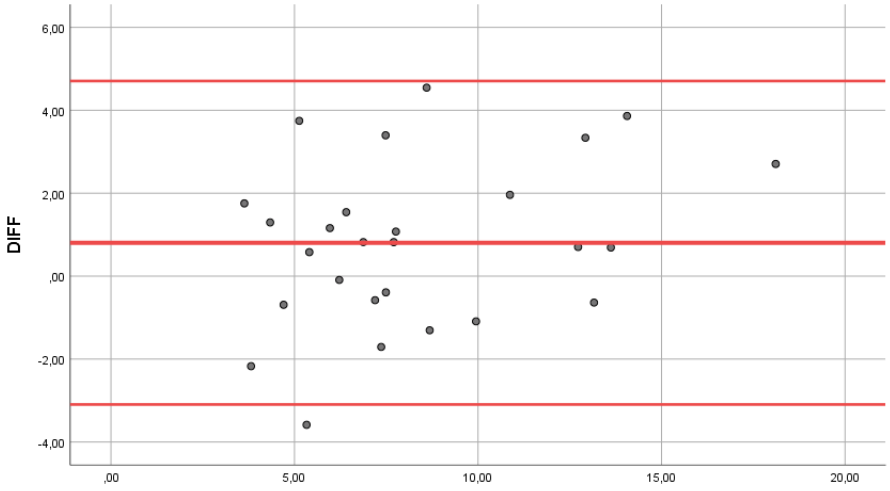


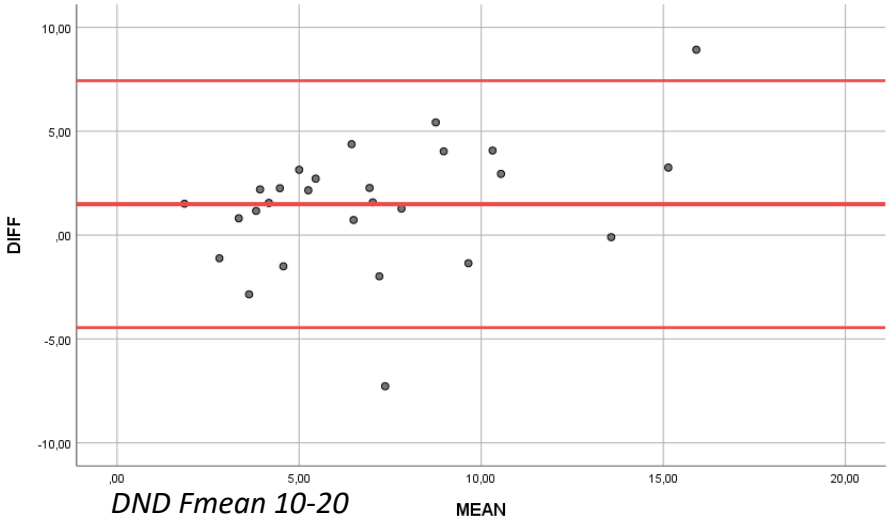
DD Fmean 10-20



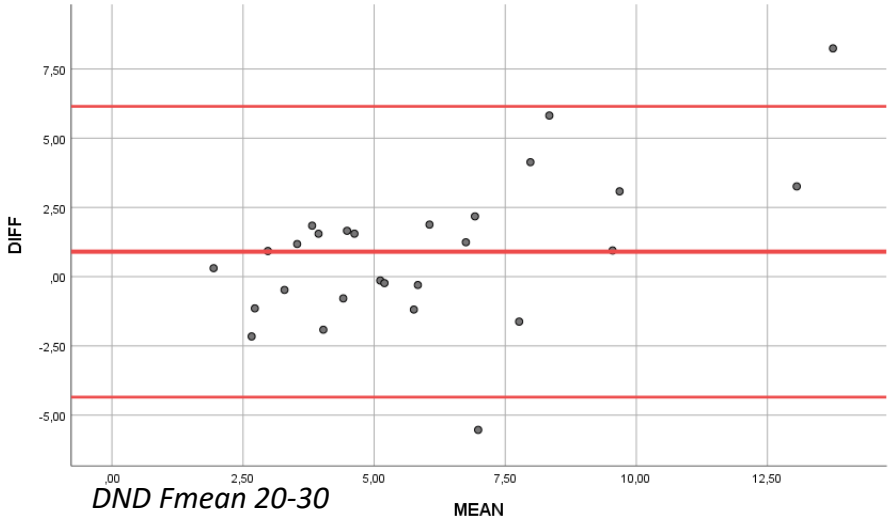
DD Fmean 20-30



DND Fmean 0-10



DND Fmean 10-20



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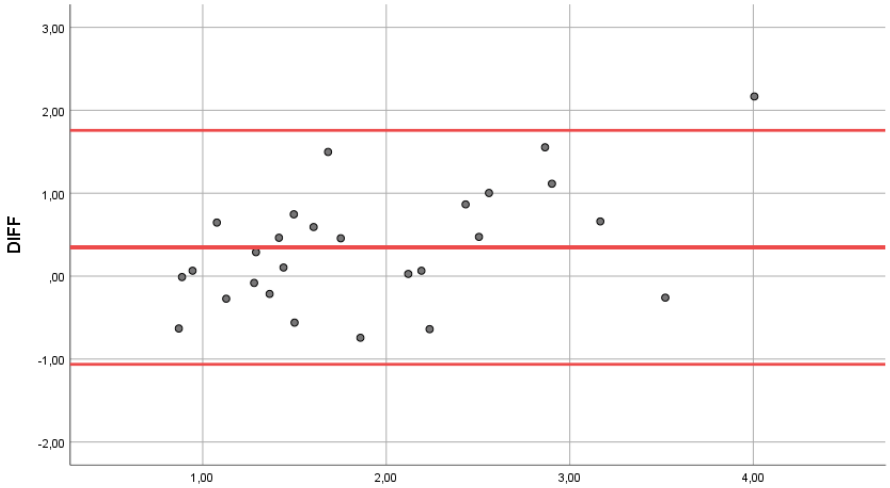
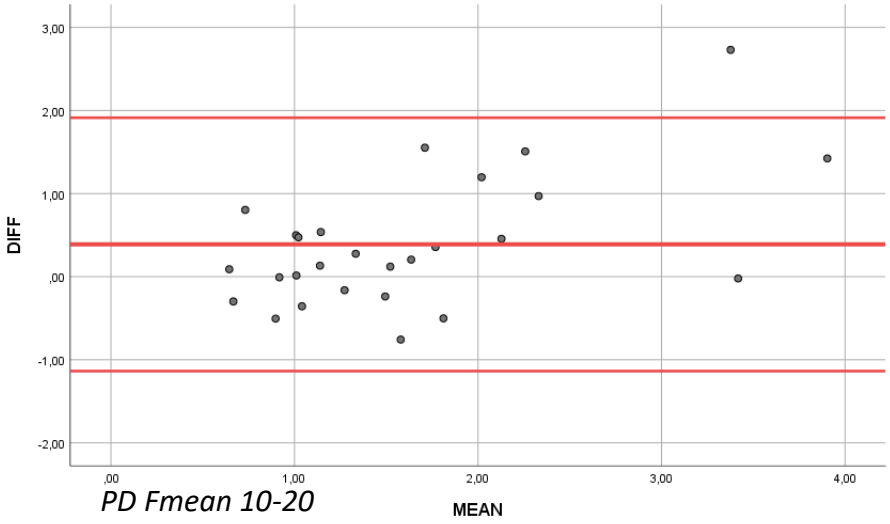
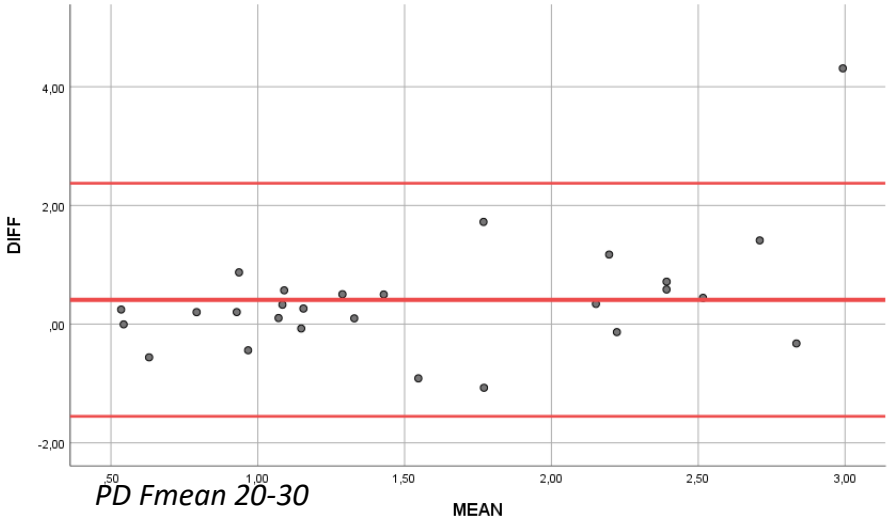


PD Fmean 0-10



PD Fmean 10-20



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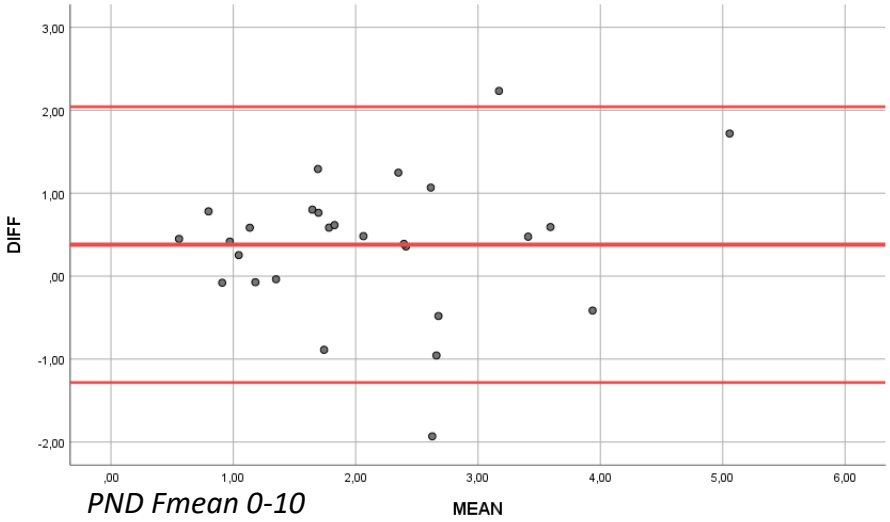

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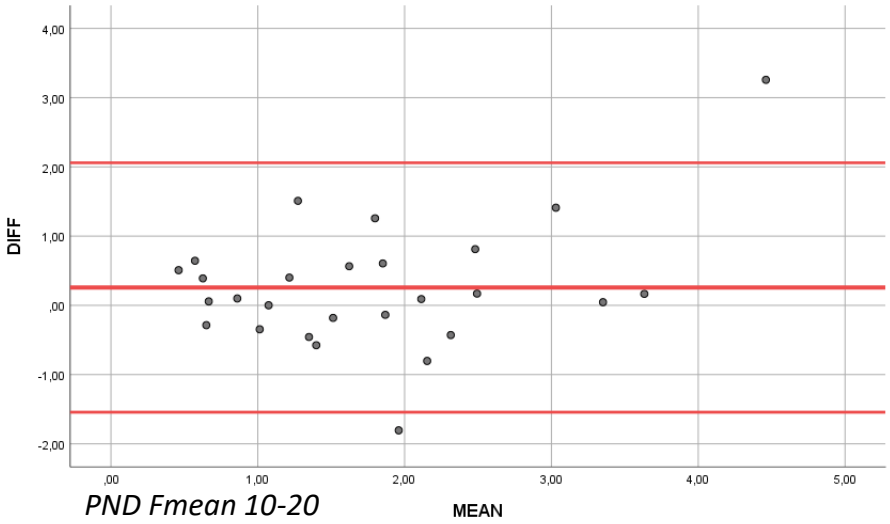
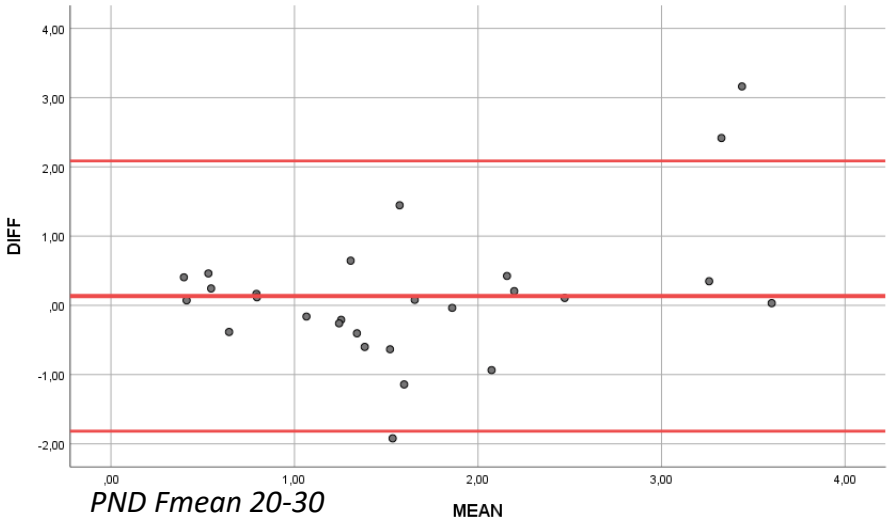


PND Fmean 10-20



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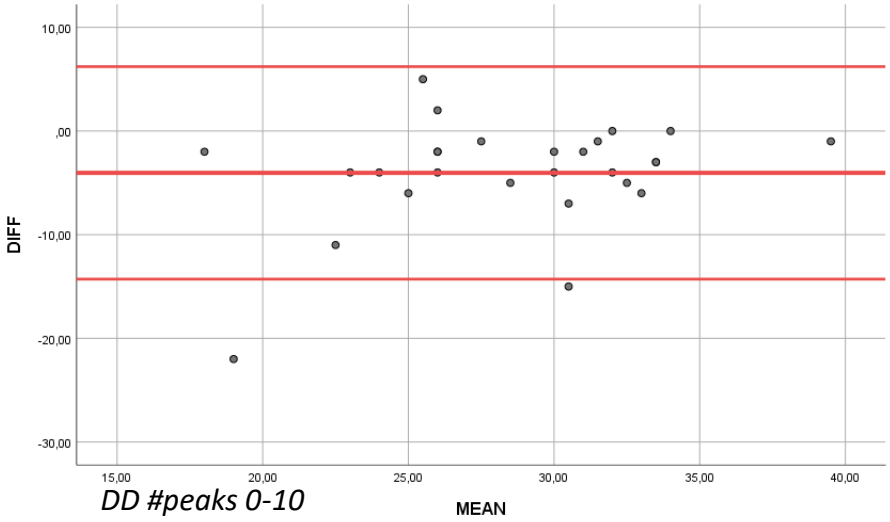

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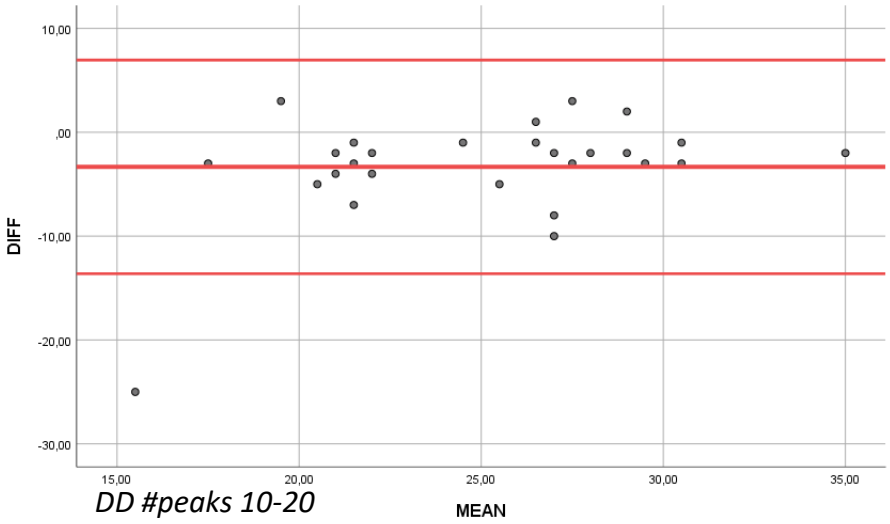

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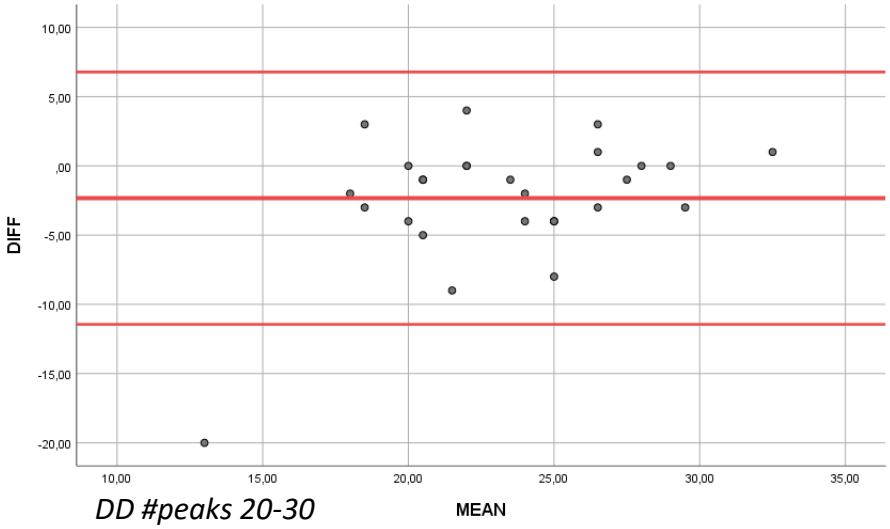
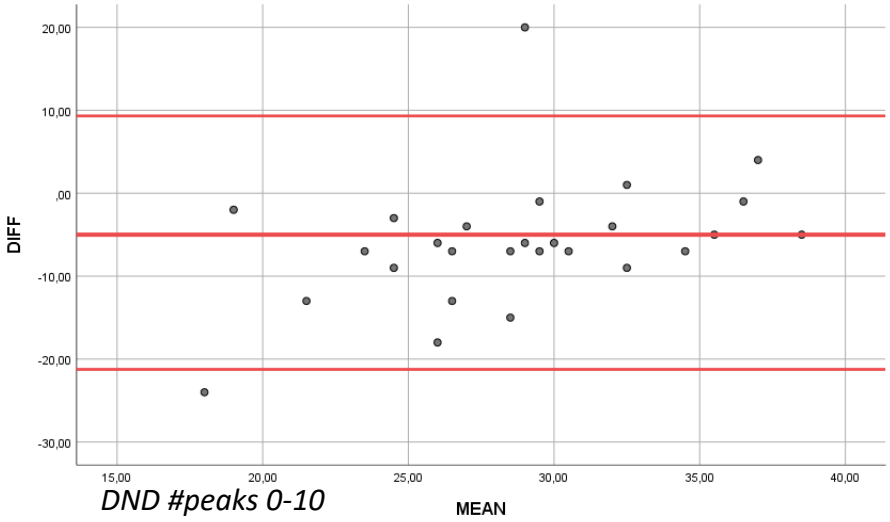
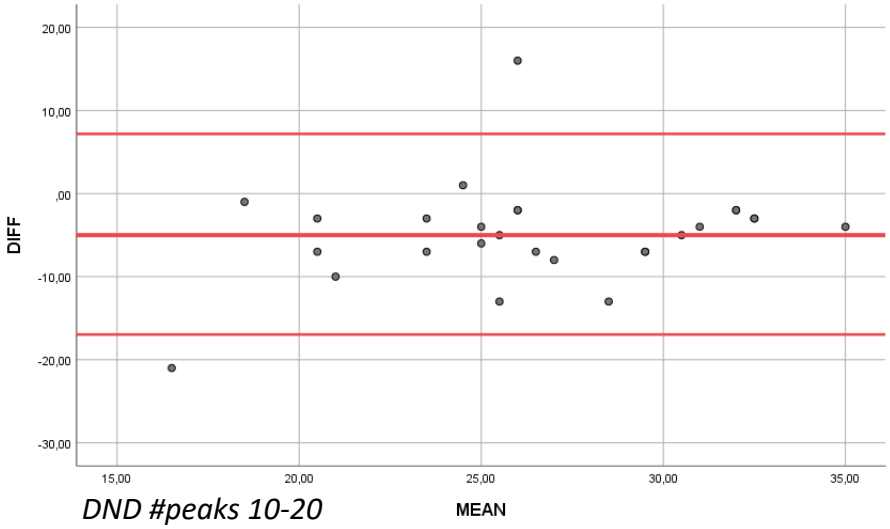


DD #peaks 20-30



DND #peaks 0-10



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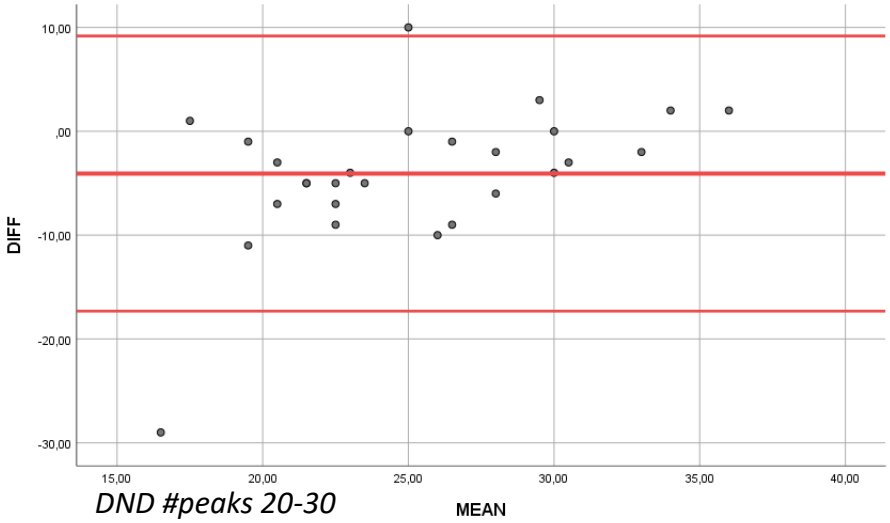

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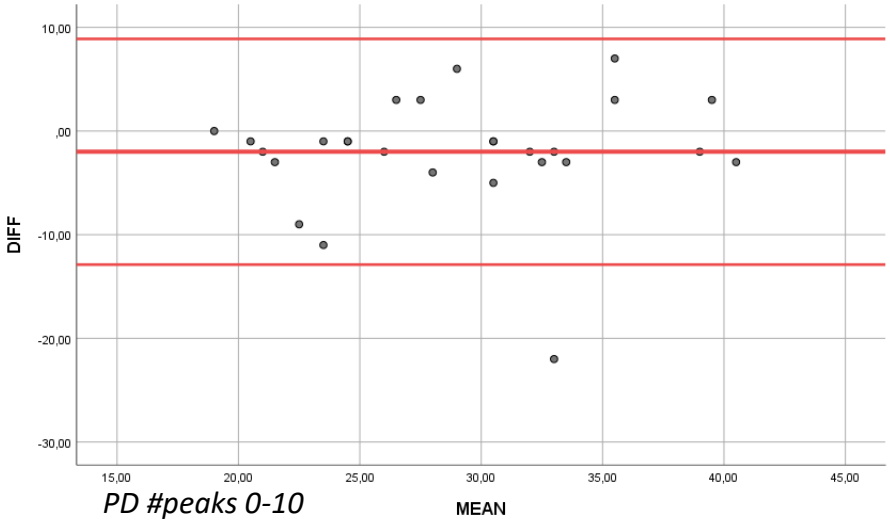

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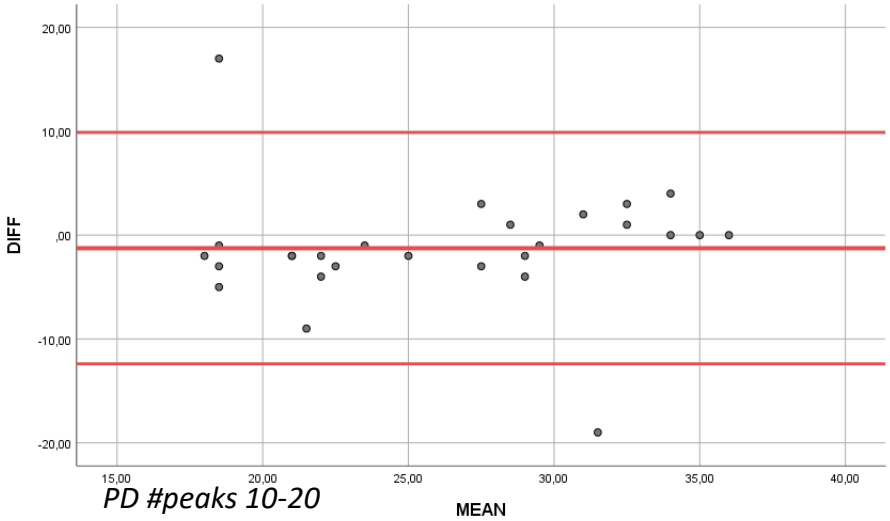

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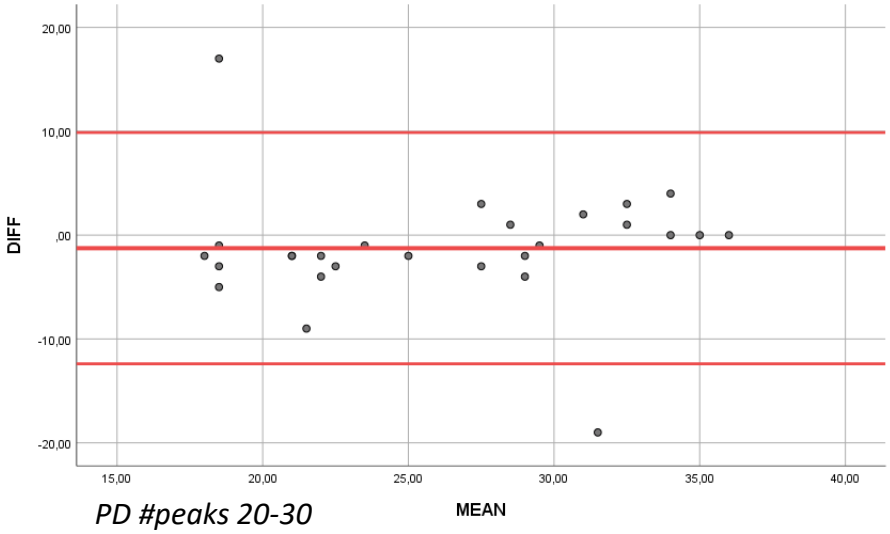

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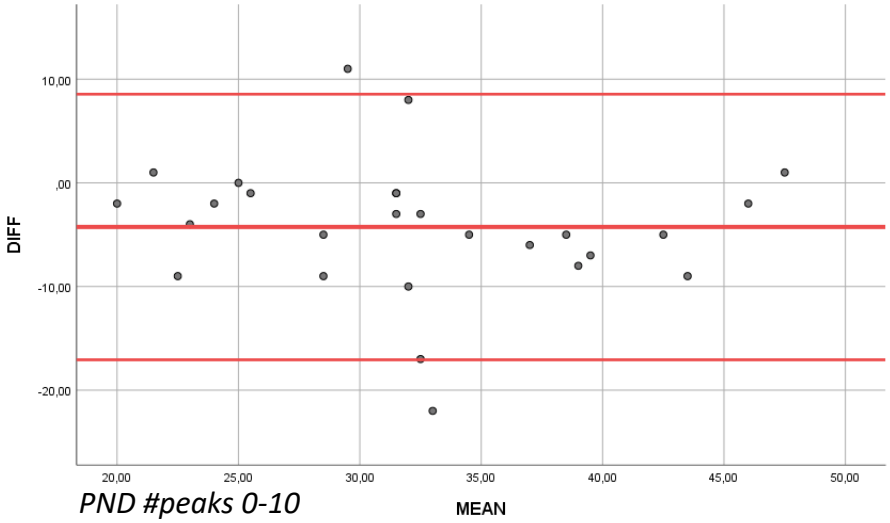

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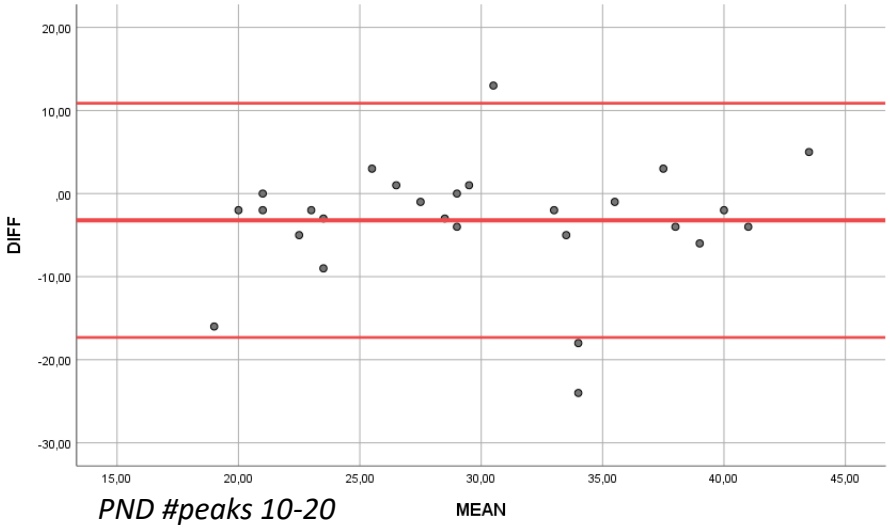

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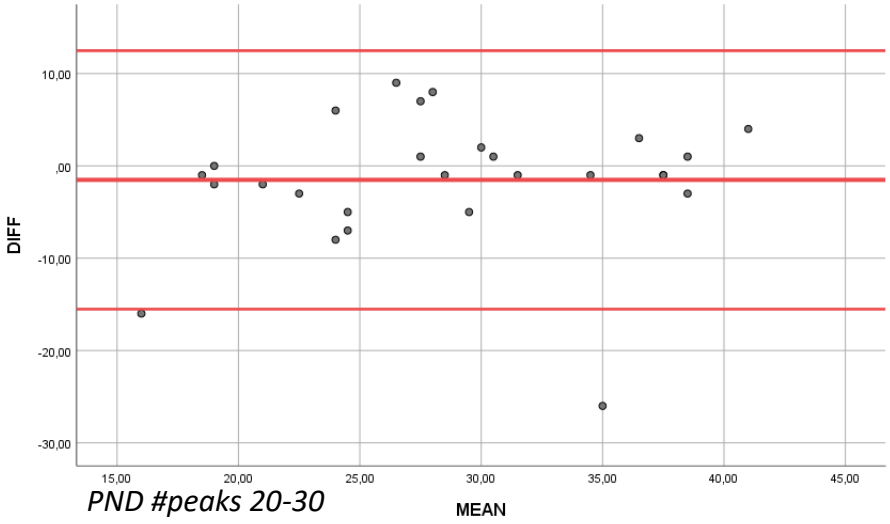

PND #peaks 20-30

Appendix 6: Inventory form

www.uhasselt.be
Campus Hasselt | Martelarenlaan 42 | BE-3500 Hasselt
Campus Diepenbeek | Agoralaan gebouw D | BE-3590 Diepenbeek
T + 32(0)11 26 81 11 | E-mail: info@uhasselt.be

UHASSELT
KNOWLEDGE IN ACTION

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
24/10/2018	Training testprotocol (UHasselt)	Promotor: Copromotor/Begeleider: Student(e): Student(e):
?	Patiënt recrutering (skype)	Promotor: Copromotor/Begeleider: Student(e): Student(e):
6/05/2019	Data-analyse opstart (skype)	Promotor: Copromotor/Begeleider: Student(e): Student(e):
13/05/2019	Data-analyse evaluatie (UHasselt)	Promotor: Copromotor/Begeleider: Student(e): Student(e):

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

Naam Student(e): Jarne Vandereyt **Datum:** 3/6/19

Titel Masterproef: Test - retest reliability of a protocol to measure dynamic fatigability in TD children

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	0	0	0	0	X	0
Methodologische uitwerking	0	0	0	0	X	0
Data acquisitie	0	0	0	0	0	X
Data management	0	0	0	0	0	X
Dataverwerking/Statistiek	0	0	0	0	X	0
Rapportage	0	0	0	0	X	0

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)
3/6/19 Vandereyt	3/6/19	