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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

A pilot study investigating the correlation between the Head Repositioning Accuracy Task and a new Weight Discrimination Task

Ricky Van Haren
Milan Vandecaetsbeek

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

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Prof. dr. Katleen BOGAERTS

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A Pilot Study Investigating the Correlation between the Head Repositioning Accuracy Task and a new Weight Discrimination Task

Research question:

"Is there a correlation between the outcome of the Head Repositioning Accuracy Task and the new Weight Discrimination Task in a healthy population?"

Highlights:

- Proprioception, a comprehensive construct consisting of several components, is of great importance for precise, coordinated movement and maintaining balance.
- Clinical tests are not available for every component (e.g. sense of weight) and the performance of tests is often highly variable.
- For this pilot study, a new standardised version of the Weight Discrimination Task was used. Results showed no significant correlation with the Head Repositioning Accuracy Task and a low internal consistency of the Weight Discrimination Task.
- This study is a first step towards a standardised, validated task to evaluate sense of weight.

Ricky Van Haren & Milan Vandecaetsbeek

Promotor: Prof. Dr. Katleen Bogaerts

Copromotors: Prof. Dr. Pieter Meyns, Prof. Dr. Lotte Janssens

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In addition, we thank our fellow students and acquaintances who contributed to sharing our invitation to participate in the study via social media. We also acknowledge the subjects who voluntarily participated in this pilot study. Without their cooperation, it would not have been possible to conduct this study.

Finally, we would like to thank the University of Hasselt for making this research possible and for the availability of the research rooms and the necessary equipment.

Research context

Proprioception can be defined as the cumulative sensory input on body position and movement to the central nervous system, arrived from specialized nerve endings called mechanoreceptors (Hasan & Stuart, 1988), in order to provide appropriate motor output. It is an important contributor to human motor control (Moon et al., 2021). For example, Han et al. (2013) showed a correlation between proprioceptive sensitivity and competition level in elite sport. Also, ageing is accompanied by a series of physiological changes that lead to a deterioration in proprioceptive functions (Bullock-Saxton et al., 2001; Ferlinc et al., 2019; Skinner et al., 1984). As optimal proprioception is crucial for balance control (Riemann & Lephart, 2002), this deterioration is linked to an increased risk of falling (Henry & Baudry, 2019), which has a huge impact on well-being (Jónsdóttir & Ruthig, 2021) as well as major socio-economic consequences (Kim et al., 2020). Fortunately, physical activity seems to play a role in maintaining and even improving proprioceptive function, making it susceptible to certain interventions (Ribeiro & Oliveira, 2007). However, proprioception was later expanded to include other senses being force, weight, muscle tension and size sense (Proske & Gandevia, 2012).

Despite this keen interest, literature research shows that one single test is not sufficient to capture proprioceptive accuracy precisely. Thus, different proprioceptive tests on different parts of the body produce other outcomes on proprioceptive accuracy (Horváth et al., 2022). Besides, there is great variability in the performance of tests to evaluate some components of proprioception. This applies, for example, to the proprioceptive sense of weight. Therefore, a standardised Weight Discrimination Task was developed by the research group. In this pilot study, correlation between the (already validated) Head Repositioning Accuracy Task and this new Weight Discrimination Task was examined in a healthy population. In addition, we evaluated the internal consistency and practical applicability of this new task.

Testing was conducted in Building A REVAL on the university campus of Diepenbeek by the research group. The results and associated paper were written by Ricky Van Haren and Milan Vandecaetsbeek for the scientific internship of the 2nd master in rehabilitation sciences and physical therapy. As a follow-up to this pilot study, the research group will examine a potentially reduced proprioceptive and interoceptive accuracy in patients with fibromyalgia, potentially adding value to the multidisciplinary treatment of this disorder. This master's thesis was thus conducted as a contribution to insights in the overlapping field of musculoskeletal and mental health care rehabilitation.

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1 Abstract

Background: Proprioception is crucial for human movement. Decreased proprioceptive accuracy occurs in various populations and leads to limitations in daily life. However, measuring proprioceptive accuracy is very complex. It consists of different components for which there is not always an appropriate task available (e.g. sense of weight). Therefore, a standardised task was developed to evaluate sense of weight and used for the first time in this pilot study.

Objectives: This pilot study attempts to clarify the following research question: "Is there a correlation between the outcome of the Head Repositioning Accuracy Task and the new Weight Discrimination Task in a healthy population?" In addition, internal consistency and practical applicability of this new task was examined.

Participants: The sample consisted of 30 healthy subjects between the ages of 18 and 65 (17 men). Average BMI was 24,35 kg/m^2 and participants spent an average of 3,67 hours on sports activities per week.

Measurements: The test procedure consisted of the following tasks: the Head Repositioning Accuracy Task and a Weight Discrimination Task. To address the research question, outcome measures of these tasks have been included within the data analysis of this pilot study.

Results: In this pilot study, no significant correlation was found between the Head Repositioning Accuracy Task and the Weight Discrimination Task (r_{29} = -.258; p = .17). Internal consistency of the Weight Discrimination Task was low (*Cronbach* α = .3006).

Conclusion: In sum, we can conclude that there is no correlation between the Head Repositioning Accuracy Task and the new weight discrimination accuracy task. Given that the internal consistency of this Weight Discrimination Task in this form is found to be fairly low, further research into the psychometric properties and development of this task should be carried out.

Keywords: proprioceptive accuracy, Head Repositioning Accuracy Task, Weight Discrimination Task

2 Introduction

Throughout the course of the past centuries, researchers have elaborated various concepts and corresponding definitions surrounding proprioception. The term proprioception was first used by neurophysiologist Sir Charles Sherrington, who describes it as the perception of joint and body movement as well as position of the body, or body segments, in space (Sherrington, 1952). Later, the term kinaesthesis often appeared in published literature, where the interpretation of the distinction from proprioception is not always clear. Kinaesthesis is sometimes considered as part of proprioception, which then consists of joint position sense (the ability to perceive the position of a joint with vision occluded) and the sensation of joint movement (Safran et al., 2001). On the contrary, some researchers view proprioception exclusively as joint position sense (Swanik et al., 2004). Modern outlook on kinaesthesis argues a combined central-peripheral mechanism where receptors of the skin, muscles and joints generate afferent signals that code for an endpoint position of a limb. These are then linked to a body map at the level of the central nervous system in order to determine the position of the limb in space (Proske & Gandevia, 2012). However, both views are somewhat incomplete as it became clear that proprioceptive mechanisms also underlie other senses such as the perception of heaviness, force and muscle tension (Proske & Gandevia, 2012).

Researchers commonly speak of proprioceptive accuracy, which refers to an individual's ability to perceive joint position, movement, trajectory; and velocity as well as the detection of the level of force, muscle tension, weight, and size of different objects (based on proprioceptive information) (Horváth et al., 2022). It is important to state that muscle spindles (in the muscle belly to process information about the length and speed of elongation during motion) are considered the main receptors for kinaesthesis and joint position sense (Grigg et al., 1973). This is different in force detection, where the tendon organ is the main receptor (Proske & Gandevia, 2012).

Sensory information from somatosensory (including proprioceptive), vestibular and visual systems are integrated by the central nervous system to provide equilibrium maintenance (Assländer & Peterka, 2014; Chiba et al., 2016). Peterka (2002) describes that in the case of a stable base in an enlightened environment, a person relies for 70% on somatosensory information to maintain balance. A deficiency in detection and processing of this afferent information consequently leads to a disturbed postural control, resulting in an increased fall risk (Wingert et al., 2014). Reduced proprioceptive function has been reported in many different populations. For example, an altered Head Repositioning Accuracy Task (HRAT) has been reported in patients with experimentally-

induced neck pain (Christensen et al., 2019). This task is used to assess neck proprioception and has already been validated (Dugailly et al., 2015). More recently, decreased proprioceptive accuracy has also been identified in patients with fibromyalgia (FM) (Celenay et al., 2019; B. Gucmen et al., 2022). Fortunately, proprioceptive training has already been shown to improve postural stability, static, and dynamic balance (Martínez-Amat et al., 2013; Riva et al., 2019) and motor function in general (Aman et al., 2014).

Literature search shows a lack of simple clinical tests with good psychometric properties to evaluate one's proprioceptive accuracy (Hillier et al., 2015). Tests to clinically assess proprioception can be divided into three categories based on their method: method of adjustment, method of constant stimuli and method of limits (Han et al., 2016). It is often assumed that scoring well on a proprioceptive accuracy task carries over to other proprioceptive accuracy tasks, but this assumption is not supported by scientific evidence (Niespodziński et al., 2018). Similarly, results of one body part may not be transferred to other parts (Horváth et al., 2022). Thus, there is no test (yet) that can provide a complete measure of proprioceptive accuracy (according to the current definition) while also being generalisable to the whole body (Horváth et al., 2022). Moreover, there is no standardised, validated test available for every component of proprioception and great variety in the implementation of same tasks exists. For example, there is a huge variety in the execution of weight discrimination tasks (for the evaluation of sense of weight) (Gardner et al., 1983; Horváth et al., 2020; Tremblay et al., 2001). Therefore, a new task was developed in which the smallest detectable weight difference of an individual is searched for by comparing different weights with a reference weight through a standardized method. This is based on an existing task to evaluate interoceptive accuracy (the respiratory occlusion discrimination task) (Van Den Houte et al., 2021). Interoception can be defined as "the overall process of how the nervous system senses, integrates, stores, and represents information about the state of the inner body" (Khalsa et al., 2018).

This pilot study compares the results of the validated HRAT with those of a new Weight Discrimination Task (WDT) in a healthy population while simultaneously assessing its internal consistency. It was conducted in preparation of a study on proprioception and interoception in patients with FM. In this way, practical application and potential clinical relevance of the WDT is examined for the first time.

3 Methods

3.1 Participants

A total of 30 participants were included in this pilot study. Recruitment of test subjects was done through online distribution of posters via social media. If interested, people could contact the research team via e-mail. Potential participants received a detailed explanation of the study design and were provided with an informed consent. In addition, they were asked to leave their telephone number and were later contacted by a member of the research team. During this contact the purpose and procedure of the study were explained and further questions were answered. The researcher went through all in- and exclusion criteria and participants were asked to indicate if they met an exclusion criterion without having to specify which one. If a participant fulfilled the following criteria, they could participate in the study at Hasselt University and were invited in Building A REVAL (Diepenbeek).

In order to be included, a person had (1) to be in good health and (2) to be between 18 and 65 years old. A person was excluded when one of the following conditions was present: (1) pregnancy, (2) under 18 or over 65 years of age, (3) a self-reported mental illness such as depression, burnout, anxiety disorder, eating disorder, substance abuse, psychotic disorder or personality disorder, (4) presence of a chronic organic disorder (chronic organic disorder is said to be present for a period of at least 3 months: e.g. epilepsy, heart disease, rheumatism, asthma, diabetes,…) or persistent physical complaints (e.g. hyperventilation complaints, long-term COVID, chronic pain or fatigue, chronic tinnitus,…), (5) the use of antidepressants, sleep medications (benzodiazepines) and anxiety-inhibiting drugs (anxiolytics), (6) neck pain at the time of testing, (7) recent whiplash trauma less than 3 months ago or more than 3 months ago with persisting symptoms, (8) diagnosis of vestibular or neurological disorders and/or (9) recent orthopaedic problems of the lower limbs (e.g. acute ankle trauma) that may affect balance, or of the upper limbs (e.g. fracture or strain injury) that may affect arm or hand strength.

3.2 Procedure

After reading and signing the informed consent, participants went through a four-part research protocol. The first step in this procedure was to carry out a questionnaire on the demographics of each person. The following characteristics were surveyed: year of birth, weight, height, sporting activities, education level, medication use, presence of medical conditions, smoking behaviour, alcohol use and infections/vaccinations regarding Covid 19. Subsequently, the following three

proprioception tasks were administered respectively: (1) a postural control task (PCT) focused on muscle vibrations of the triceps surae muscle and the lumbar multifidii muscles according to the method of (Claeys et al., 2015), (2) the HRAT and (3) the WDT. Outcome measures of the HRAT and WDT are further included in the statistical analysis of this research, a detailed explanation of the tests can be found in the following paragraphs. Since the PCT falls outside the scope of the current study, this task is not included in the data analysis.

3.2.1 Head Repositioning Accuracy Task

Because of its established test-retest reliability (ICC = 0.80) (Pinsault et al., 2008), the procedure of Revel et al. (1991) was used within this task to evaluate the subjects degree of neck proprioception. At the start of the test, each participant sat in a relaxed position against the backrest looking straightforward, while wearing blinding glasses and a laser headlamp. A paper was attached to the wall 90 cm away from the participants head height in sitting. Participants were asked to find their neutral head position, which was then indicated on the wall (laser point). From this position, participants actively turned their head to the right and attempted to return to their neutral position. This position was again marked on the wall. This procedure was performed five times consecutively to the right and left, with each new attempt the head being passively returned to the starting position by the examiner. The overall average and the average per side were then calculated from the distance (margin of error) in cm between the marked points and the indicated starting point. Revel et al. (1991) stated that in healthy individuals a margin of error less than 7.1 cm indicates a normal degree of neck proprioception (sensitivity = 86%; specificity = 93%).

3.2.2 Weight Discrimination Task

The WDT is a new standardised task aiming to analyse the minimum difference in weight that a person can distinguish with the upper limb. For this purpose, a transformed adaptive staircase paradigm was used (Leek, 2001). This procedure has already been implemented in a protocol for the determination of respiratory interoceptive accuracy (Van Den Houte et al., 2021). Hereby the implemented staircase paradigm allowed to specify the minimum difference in weight (= just noticeable difference (JND)) that a person could differentiate 70,7% of the time within the WDT. This was done by determining the 70.7% correct differentiation point of the psychometric function after completion of the task (Levitt, 1971).

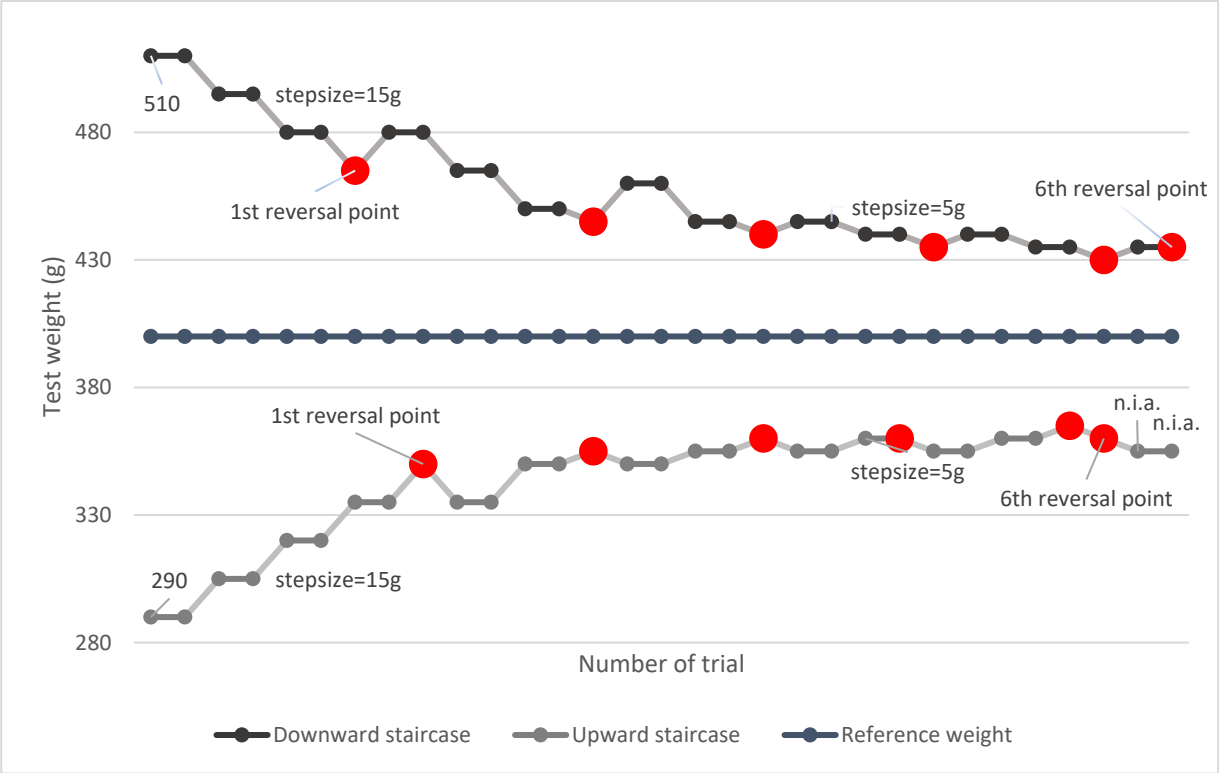
During the WDT, two glass bottles were successively given, one of which always had a reference weight of 400 grams and one different test weight. The current WDT paradigm, incorporated in

our software programme, consisted of a downward going staircase (approaching the reference weight of 400g with heavier test weights) and upward going staircase (approaching the reference weight of 400g with lighter test weights) as shown in Figure 1. Both staircases were started with the reference weight and the minimum test weight of 290g or the maximum test weight of 510g. At the start of the measurement, each participant sat on a chair and wore blinding glasses. The dominant arm was bent 90 degrees at the level of the elbow, with the upper arm resting against the trunk. The participant had to hold each bottle for six seconds and was not allowed to move. These time intervals were indicated by a beep signal using the computer software. When the second bottle was given back, the participant had to stretch his arm and indicate which was the heaviest. Based on this answer, the computer software determined the following weight that a test subject had to compare with the reference weight. The participant had to return to the original starting position at each trial, order of the reference weight and test weight was always randomised. In addition, the software algorithm ensured that both staircases were alternated, meaning that each uneven trial belonged to the downwards going staircase and each even trial to the upwards going staircase. According to the adaptive staircase paradigm, the participant received a more difficult combination of weights after two consecutive correct answers and an easier combination after one wrong answer. A step-size of 15 grams was used in both staircases and changed into 5 grams if a participant managed to be within a range of 50 grams from the reference weight (350-450 grams).

The WDT ended when a participant had made six mistakes (= reversal points) in each staircase, the software then calculated the JND per staircase as the outcome measure of the WDT. If one staircase reached its sixth reversal point before the other, it continued to run without being processed for data analysis after that specific point (see Figure 1). The software calculated the JND per staircase as the outcome measure of the WDT. Because of possible fatigue, each participant was given a short break after 10 minutes.

Figure 1

Example of WDT Procedure



n.i.a. = not included in analysis, red dot = reversal point

3.3 Data analysis

The software program JMP Pro 16.2.0 (SAS Institute USA) was used to perform the data analysis of this pilot study (significance level: p = .05). The descriptive statistics (mean value and standard deviation) were calculated for the following sample characteristics: age, gender, BMI, and the weekly number of hours of sport.

Thereafter, MatLab was used to calculate the average of the upward JND (average difference between the reference weight and the six reversal points of the upward staircase) and downward JND (average difference between the reference weight and the six reversal points of the downward staircase) of the WDT for each participant. In this way, the overall JND score was obtained as main outcome measure of the WDT. The mean score and standard deviation of the upward, downward and overall JND of the WDT and average HRAT-score were computed, normality was verified using a *Shapiro-Wilk* test. If the outcome measures of the WDT and/or HRAT were not normally distributed, a BoxCox transformation was applied. In addition, the average duration and number of trials of the WDT were examined.

Overall JND-score of the WDT and the average HRAT-score were used to calculate the Pearson correlation between these proprioception tasks. For both scores, a higher outcome value indicates a poorer degree of proprioceptive accuracy.

In addition, internal consistency was analysed using a paired sample t-test and by calculating Cronbach's alpha to assess the psychometric properties of the WDT. For this purpose, the downward JND and upward JND were used.

4 Results

4.1 Sample characteristics

The mean age of the study group (n=30) was 32.66 years (*SD* = 13.62; range = 19-64 years). The study sample consisted of 17 male and 13 female participants. The average BMI was 24,35 kg/m^2 (*SD* = 3.90; range = 19.44-35.86). The participants spent an average of 3.67 hours on sports activities per week (*SD* = 3.01; range = 0-14).

4.2 Performance of the WDT

Within the WDT, the average overall JND was 37.12 grams (*SD* = 13.42; range = 13.75-73.33) and normally distributed (*Shapiro-Wilk*: p = .79). This meant that on average, 70.7% of the time, a participant could differentiate a weight that was only 37.12 grams different from the reference weight (400 grams). The average downward JND was 4.42 grams (*SD* = 17.88; range = 11.67-75.00 grams) and the average upward JND was 39.83 grams (*SD* = 17.44; range = 10.00-82.50 grams). Upward JND was normally distributed (*Shapiro-Wilk*: p = .33), but downward JND wasn't (*Shapiro-Wilk*: p = .032). Participants needed an average of 22.26 minutes (*SD* = 4.29, range = 15.47-33.88 minutes) with an average number of 64 trials (*SD* = 10.26; range = 48-94 trials) until the 6th reversal for both staircases was reached. The average trial number and test weight per reversal point can be found in Table 1.

4.3 Performance of the HRAT

The average HRAT-score was 4.8 cm (*SD* = 2.65; range = 2.5-14.4 cm) and not normally distributed (*Shapiro-Wilk*: p < .001). This means that the margin of error during this test was on average 4.8 cm from the marked starting point.

4.4 Correlation between the WDT and HRAT

Since the average HRAT score was not normally distributed, this outcome measure had to be transformed [=(HRAT ^ (-1.065) - 1) / -.0517283509470852] before a correlation between the WDT and HRAT could be calculated. No significant correlation could be found between the WDT and HRAT (r_{29} = -.258; p = .17).

4.5 Internal consistency of the WDT

As mentioned earlier, the average downward and upward JND were used to assess the internal consistency of the WDT. As the average downward JND was not normally distributed, both outcome measures were transformed [=(JND ^ .135 - 1) / 0.0070986612849465] to perform a

paired sample t-test. This showed that average JND is significantly lower in the upwards going staircase than the downwards going staircase (t_{29} = 1.448; p = .16). Cronbach's alpha was .301 and no significant correlation between the average upward and downward JND was found (r_{29} = 0.177; p = .35), suggesting poor internal consistency (Bland & Altman, 1997).

Table 1

Average trial number and test weight per reversal point

	Downward going staircase				**Upwards going staircase**			
	Trial number		**Test weight**		**Trial number**		**Test weight**	
Reversal #	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***
1	22.27	8.44	436.50	26.82	21.73	6.84	359.00	23.83
2	27.20	9.25	449.50	25.20	26.40	7.56	346.33	21.65
3	37.40	8.54	430.17	19.93	36.26	9.46	364.83	18.87
4	42.93	9.39	437.67	18.88	42.53	10.48	355.83	18.53
5	52.13	9.74	424.83	13.42	52.53	11.41	369.67	17.22
6	57.67	10.22	427.83	12.37	58.67	12.38	365.33	15.14

5 Discussion

The aim of this pilot study was to investigate a possible correlation between the HRAT and a new WDT within a healthy study sample. Additionally, the internal consistency of this WDT was analysed. The data analysis showed that there was no significant correlation between these two proprioception tasks and that the internal consistency of the WDT was low.

First of all, the results of our pilot are of importance for a future study of our research group on proprioception and interoception in patients with FM. Recent studies conclude that this target group has poorer performance in several proprioception tasks. For example, Burhan Gucmen et al. (2022) demonstrated that patients with FM score worse on both a cervical joint position error test (CJPET) and different balance tests (Single Leg Stance Test, Timed Up and Go test, one legged balance test). In addition, this study found that higher disease activity was associated with a poorer CJPET-score and performance of the balance tests was correlated with the CJPET. Vaillant et al. (2017) supports these results, as they found a negative alteration in neck proprioceptive capacity in women with FM compared to healthy subjects using the Cervicocephalic Relocation Test. Nevertheless, research on proprioception within the FM population is still quite limited. The procedure of this pilot study will be part of future research investigating interoception and proprioception in FM. Therefore, the results from this pilot study can be used to check whether there is a difference in correlation between HRAT and WDT performance in FM patients and healthy individuals.

As mentioned earlier, data analysis showed no correlation between the HRAT and WDT. Nevertheless, this result seems to be in line with current scientific literature on proprioception in healthy subjects. A recent systematic literature review of Horváth et al. (2022) concluded that no study could be found in which a correlation was established between two different proprioception accuracy tasks in healthy subjects. This may seem paradoxical, but is actually quite logical if we take a closer look at the measurement techniques of existing proprioception accuracy tests. Gescheider (1997) made the distinction between the method of adjustment, method of constant stimuli and method of limits. According to this classification, we could categorise the WDT of this pilot study under the method of constant stimuli. This method attempts to determine the degree of proprioceptive accuracy by assessing the minimum threshold a person can distinguish between two stimuli of different intensity (Han et al., 2016). This is done by having a subject compare a constant stimulus with a random stimulus in random order (e.g. discrimination of movement, weight, object size or joint position). Within the WDT, this procedure was implemented by

comparing a reference weight of 400 grams to a different test weight to determine a participant's JND within an adaptive staircase paradigm. On the contrary, the HRAT can be categorised as the method of adjustment (also known as the method of average error). Proprioception accuracy tasks belonging to this subgroup consider the ability to reproduce a reference stimulus or position (Han et al., 2016). Here, the test subject starts from a level that is clearly different from the reference stimulus (= head rotation in the HRAT) and subsequently must approach this reference stimulus (= neutral head position in the HRAT) as precisely as possible. The average error rate of a person is then considered as the outcome measure of proprioception accuracy within these tasks. Since there is a difference in measurement method between the HRAT and WDT, the possibility to find a correlation between these tasks is therefore less likely. Another important element that should be considered regarding the interpretation of the results is the difference in proprioceptive components and body parts assessed by the WDT and HRAT. Horváth et al. (2022) already showed that it cannot be assumed that one particular test with respect to one particular body part can be generalized if we want to assess the overall proprioception accuracy of a person. In other words, the best performer in one specific test (e.g. HRAT) with respect to a certain part of the body (head) may not be the best performer in another test (e.g. WDT) assessing another body part (elbow). This becomes more clear when we take a closer look at the proprioception tasks within this pilot study. The HRAT is a test that focuses on the aspect of position and movement sense within proprioception. Since a subject is blinded during this test, the rate of discharge in primary and secondary muscle spindles of the neck musculature will mainly be responsible to inform the brain about the position and movement of the head (Proske & Gandevia, 2012). As the name of the test implies, the WDT focuses on the component of weight sense within proprioception. In contrast to the HRAT, in which the blinded subject will have to use the tendon organs of the elbow flexors to detect the difference in weight (Proske & Gandevia, 2012). Both proprioception tasks therefore differ in the afferent structure on which a subject must rely, which means that the outcome measure of the test is determined by a different proprioceptive pathway.

For the first time, a standardised version of the WDT was developed and tested. The staircase paradigm provides an accurate estimate of the JND by using different reversal points to calculate the JND. In addition, randomising the order of the weights avoids pattern recognition. Moreover, precautions were included in the WDT protocol to exclude the confounding effects of physical and mental fatigue on proprioceptive accuracy. This was done by giving a break after ten minutes and allowing the arm to stretch between each pair of weights.

This new standardised WDT may become an important addition to the existing measuring instruments to adequately investigate proprioceptive accuracy. As stated earlier, psychometric properties of the current proprioception tasks are often inadequate and hardly clinically applicable. Additionally, a lack of clinically robust tests assessing the sense of effort and force exists, as the majority of current clinical proprioception tasks focus on position and movement sense within the domain of proprioception (Hillier et al., 2015).

Since this concerns a pilot study, the low number of participants limits the generalisability of the results. Although the new WDT was performed in a standardised way using an adaptive staircase paradigm, possible confounding variables must be considered. The average duration of the WDT was 22.26 minutes within this pilot study. This ensures that any increase in physical and mental fatigue of a subject could potentially affect the outcome measures. Unfortunately, it cannot be excluded with absolute certainty that the aforementioned precautionary measures can completely counteract these possible confounding variables. For example, Jones and Hunter (1983) emphasis that there is an increased sensation of perceived force during fatiguing isometric contractions of the elbow flexors. Nevertheless, the weights of the WDT never exceed 510 grams, so the degree of physical fatigue due to isometric contractions will be presumably lower despite the long test duration. In addition, mental fatigue may have a possible impact on the reversal points in both staircases. Since the subject must always indicate after each pair of weights which is the heaviest, this requires sustained attention throughout the whole task. Consequently, if a participant required to guess not because of his degree of proprioceptive accuracy but loss of attention, the sixth reversal point may be reached more quickly within a staircase. Even guessing itself could be a distorting factor within the WDT, as a participant must always answer even if he cannot feel the difference in weight. So, as one guesses better or worse, the overall JND score may also differ more from the person's true degree of weight discrimination.

When considering future application of the task, we should note that there are some barriers to its clinical use. First, many different weights are required to determine a JND with the use of this task. However, once the appropriate equipment is at hand, the task is easily performed by examiners requiring little skill. Moreover, with an average duration of 22.26 minutes, this task is quite time-consuming. Last, disturbing factors of the environment are easier to exclude in the laboratory setting than in clinical practice. In the future, ways of modifying the task may be explored to further reduce these limitations. However, once these limitations are addressed, this task can become an important tool to assess sense of weight in clinical practice. This can apply both in

healthy subjects as well as subjects with musculoskeletal, neurological or psychopathological disorders.

Now that it is finally possible to measure the degree of proprioceptive accuracy for the component weight discrimination with a standardised task, many opportunities for future research will arise. First, psychometric properties of the WDT test itself should be further investigated. For example, no data is available on test-retest reliability of this new task. Besides that, construct validity of the WDT should be assessed with respect to another proprioception accuracy task using the method of constant stimuli and/or assessing the same body part. In addition, weight discrimination should be evaluated in healthy populations with larger sample sizes and patient populations. Finally, the effect of fatigue on performance of the joint position sense component has already been extensively examined for different body parts (Carpenter et al., 1998; Karagiannopoulos et al., 2020). However, the effect of fatigue on the JND in a weight discrimination task has not yet been investigated. In summary, it can be concluded that the current basis of the test already consists of a well-standardized paradigm. However, the WDT needs to be further developed and the psychometric properties evaluated in order for this task to become an important standardised proprioception test within this field of science.

6 Conclusion

The aim of this pilot study was to evaluate the internal consistency of the new WDT and its correlation with the HRAT. The research procedure and associated results will be included in the analysis of a later study on interoception and proprioception in patients with FM. In sum, it can be concluded that there is no correlation between the results of the HRAT and WDT in healthy subjects. Additional analysis showed that internal consistency of the WDT in its current form is fairly low. However, further research needs to be done to further identify the psychometrics properties of this new task.

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Appendix

Verklaring op Eer

Ondergetekende, student aan de Universiteit Hasselt (UHasselt), faculteit Revalidatiewetenschappen en Kinesitherapie aanvaardt de volgende voorwaarden en bepalingen van deze verklaring:

1. Ik ben ingeschreven als student aan de UHasselt in de opleiding 2e Master Revalidatiewetenschappen en Kinesitherapie, waarbij ik de kans krijg om in het kader van mijn opleiding mee te werken aan onderzoek van de faculteit Revalidatiewetenschappen en Kinesitherapie aan de UHasselt. Dit onderzoek wordt beleid door Prof. Dr. Katleen Bogaerts en kadert binnen het opleidingsonderdeel Wetenschappelijke Stage deel 2. Ik zal in het kader van dit onderzoek creaties, schetsen, ontwerpen, prototypes en/of onderzoeksresultaten tot stand brengen in het domein van pijn, vermoeidheid en somatisch onverklaarbare klachten (hierna: "De Onderzoeksresultaten").

2. Bij de creatie van De Onderzoeksresultaten doe ik beroep op de achtergrondkennis, vertrouwelijke informatie[1], universitaire middelen en faciliteiten van UHasselt (hierna: de "Expertise").

3. Ik zal de Expertise, met inbegrip van vertrouwelijke informatie, uitsluitend aanwenden voor het uitvoeren van hogergenoemd onderzoek binnen UHasselt. Ik zal hierbij steeds de toepasselijke regelgeving, in het bijzonder de Algemene Verordening Gegevensbescherming (EU 2016-679), in acht nemen.

4. Ik zal de Expertise (i) voor geen enkele andere doelstelling gebruiken, en (ii) niet zonder voorafgaande schriftelijke toestemming van UHasselt op directe of indirecte wijze publiek maken.

5. Aangezien ik in het kader van mijn onderzoek beroep doe op de Expertise van de UHasselt, draag ik hierbij alle bestaande en toekomstige intellectuele eigendomsrechten op De Onderzoeksresultaten over aan de UHasselt. Deze overdracht omvat alle vormen van intellectuele eigendomsrechten, zoals onder meer – zonder daartoe beperkt te zijn – het auteursrecht, octrooirecht, merkenrecht, modellenrecht en knowhow. De overdracht geschiedt in de meest volledige omvang, voor de gehele wereld en voor de gehele beschermingsduur van de betrokken rechten.

6. In zoverre De Onderzoeksresultaten auteursrechtelijk beschermd zijn, omvat bovenstaande overdracht onder meer de volgende exploitatiewijzen, en dit steeds voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding:

   - het recht om De Onderzoeksresultaten vast te (laten) leggen door alle technieken en op alle dragers;

[1] Vertrouwelijke informatie betekent alle informatie en data door de UHasselt meegedeeld aan de student voor de uitvoering van deze overeenkomst, inclusief alle persoonsgegevens in de zin van de Algemene Verordening Gegevensbescherming (EU 2016/679), met uitzondering van de informatie die (a) reeds algemeen bekend is; (b) reeds in het bezit was van de student voor de mededeling ervan door de UHasselt; (c) de student verkregen heeft van een derde zonder enige geheimhoudingsplicht; (d) de student onafhankelijk heeft ontwikkeld zonder gebruik te maken van de vertrouwelijke informatie van de UHasselt; (e) wettelijk of als gevolg van een rechterlijke beslissing moet worden bekendgemaakt, op voorwaarde dat de student de UHasselt hiervan schriftelijk en zo snel mogelijk op de hoogte brengt.

- het recht om De Onderzoeksresultaten geheel of gedeeltelijk te (laten) reproduceren, openbaar te (laten) maken, uit te (laten) geven, te (laten) exploiteren en te (laten) verspreiden in eender welke vorm, in een onbeperkt aantal exemplaren;
- het recht om De Onderzoeksresultaten te (laten) verspreiden en mee te (laten) delen aan het publiek door alle technieken met inbegrip van de kabel, de satelliet, het internet en alle vormen van computernetwerken;
- het recht De Onderzoeksresultaten geheel of gedeeltelijk te (laten) bewerken of te (laten) vertalen en het (laten) reproduceren van die bewerkingen of vertalingen;
- het recht De Onderzoeksresultaten te (laten) bewerken of (laten) wijzigen, onder meer door het reproduceren van bepaalde elementen door alle technieken en/of door het wijzigen van bepaalde parameters (zoals de kleuren en de afmetingen).

De overdracht van rechten voor deze exploitatiewijzen heeft ook betrekking op toekomstige onderzoeksresultaten tot stand gekomen tijdens het onderzoek aan UHasselt, eveneens voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding.

Ik behoud daarbij steeds het recht op naamvermelding als (mede)auteur van de betreffende Onderzoeksresultaten.

7. Ik zal alle onderzoeksdata, ideeën en uitvoeringen neerschrijven in een "laboratory notebook" en deze gegevens niet vrijgeven, tenzij met uitdrukkelijke toestemming van mijn UHasseltbegeleider Prof. Dr. Katleen Bogaerts.

8. Na de eindevaluatie van mijn onderzoek aan de UHasselt zal ik alle verkregen vertrouwelijke informatie, materialen, en kopieën daarvan, die nog in mijn bezit zouden zijn, aan UHasselt terugbezorgen.

Gelezen voor akkoord en goedgekeurd,

Naam: Milan Vandecaetsbeek_____

Adres: Hombroekstraat 3A 3730 Hoeselt_____

Geboortedatum en –plaats : 04/06/1999 Te Tongeren_____

Datum: 12/10/2021_____

Handtekening:_____

UHASSELT

Verklaring op Eer

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4. Ik zal de Expertise (i) voor geen enkele andere doelstelling gebruiken, en (ii) niet zonder voorafgaande schriftelijke toestemming van UHasselt op directe of indirecte wijze publiek maken.

5. Aangezien ik in het kader van mijn onderzoek beroep doe op de Expertise van de UHasselt, draag ik hierbij alle bestaande en toekomstige intellectuele eigendomsrechten op De Onderzoeksresultaten over aan de UHasselt. Deze overdracht omvat alle vormen van intellectuele eigendomsrechten, zoals onder meer – zonder daartoe beperkt te zijn – het auteursrecht, octrooirecht, merkenrecht, modellenrecht en knowhow. De overdracht geschiedt in de meest volledige omvang, voor de gehele wereld en voor de gehele beschermingsduur van de betrokken rechten.

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[1] Vertrouwelijke informatie betekent alle informatie en data door de UHasselt meegedeeld aan de student voor de uitvoering van deze overeenkomst, inclusief alle persoonsgegevens in de zin van de Algemene Verordening Gegevensbescherming (EU 2016/679), met uitzondering van de informatie die (a) reeds algemeen bekend is; (b) reeds in het bezit was van de student voor de mededeling ervan door de UHasselt; (c) de student verkregen heeft van een derde zonder enige geheimhoudingsplicht; (d) de student onafhankelijk heeft ontwikkeld zonder gebruik te maken van de vertrouwelijke informatie van de UHasselt; (e) wettelijk of als gevolg van een rechterlijke beslissing moet worden bekendgemaakt, op voorwaarde dat de student de UHasselt hiervan schriftelijk en zo snel mogelijk op de hoogte brengt.

- het recht om De Onderzoeksresultaten geheel of gedeeltelijk te (laten) reproduceren, openbaar te (laten) maken, uit te (laten) geven, te (laten) exploiteren en te (laten) verspreiden in eender welke vorm, in een onbeperkt aantal exemplaren;
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8. Na de eindevaluatie van mijn onderzoek aan de UHasselt zal ik alle verkregen vertrouwelijke informatie, materialen, en kopieën daarvan, die nog in mijn bezit zouden zijn, aan UHasselt terugbezorgen.

Gelezen voor akkoord en goedgekeurd,

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UHASSELT
KNOWLEDGE IN ACTION

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
14/10/22	Bespreking onderzoeksopzet (online)	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
27/10/22	Bespreking onderzoeksopzet (online)	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
03/11/22	Bespreking literatuur rond vragenlijsten en proprioceptie (online)	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
01/03/22	Bespreking betreft voorbereidingen voor metingen pilootstudie (online)	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
11/05/22	Bespreking statistische analyse en verder vragen rond uitschrijven methode en resultatensectie (online) + feedback inleiding en methode via mail	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
18/05/22	Feedback resultatensectie via mail	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
23/05/22	Feedback thesis van hoofdpromotor (Prof. Dr. Bogaerts) via mail	Promotor: online Copromotor/Begeleider: / Student(e): online Student(e): online
24/05/22	Feedback thesis van copromotor (Prof. Dr. Janssens) via mail	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
25/05/22	Feedback discussie/conclusie via mail	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
01/06/22	Feedback finale thesisversie via mail	Promotor: / Copromotor/Begeleider: online Student(e): online Student(e): online
		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): ..... **Datum:**.....

Titel Masterproef: .....

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.

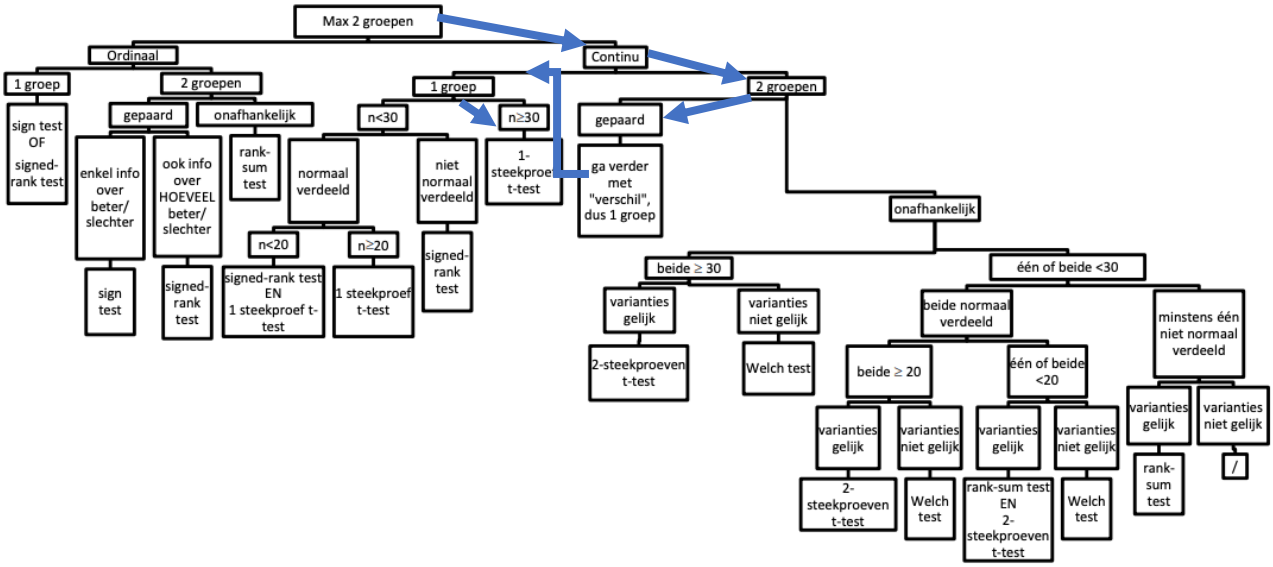
Competenties	**NVT**	**1**	**2**	**3**	**4**	**5**
Opstelling onderzoeksvraag	O	O	O	O	O	O
Methodologische uitwerking	O	O	O	O	O	O
Data acquisitie	O	O	O	O	O	O
Data management	O	O	O	O	O	O
Dataverwerking/Statistiek	O	O	O	O	O	O
Rapportage	O	O	O	O	O	O

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)


Max 2 groepen
Ordinaal
1 groep
sign test OF signed-rank test
2 groepen
gepaard
enkel info over beter/ slechter
sign test
ook info over HOEVEEL beter/ slechter
signed-rank test
onafhankelijk
rank-sum test
signed-rank test EN 1 steekproef t-test
normaal verdeeld
n<20
n≥20
1 steekproef t-test
niet normaal verdeeld
signed-rank test
Continu
1 groep
n<30
n≥30
1-steekproef t-test
gepaard
ga verder met "verschil", dus 1 groep
2 groepen
onafhankelijk
beide ≥ 30
variantie gelijk
2-steekproeven t-test
variantie niet gelijk
Welch test
één of beide <30
beide normaal verdeeld
beide ≥ 20
variantie gelijk
2-steekproeven t-test
variantie niet gelijk
Welch test
één of beide <20
variantie gelijk
rank-sum test EN 2-steekproeven t-test
variantie niet gelijk
Welch test
minstens één niet normaal verdeeld
variantie gelijk
rank-sum test
variantie niet gelijk
/

Inschrijvingsformulier verdediging masterproef academiejaar 2021-2022,
Registration form jury Master's thesis academic year 2021-2022,

GEGEVENS STUDENT - *INFORMATION STUDENT*

Faculteit/School: **Faculteit Revalidatiewetenschappen**
Faculty/School: ***Rehabilitation Sciences***

Stamnummer + naam: **1745640 Vandecaetsbeek Milan**
Student number + name

Opleiding/*Programme*: **2 ma revalid. & kine musc.**

INSTRUCTIES - *INSTRUCTIONS*

Neem onderstaande informatie grondig door.

Print dit document en vul het aan met DRUKLETTERS.

In tijden van van online onderwijs door COVID-19 verstuur je het document (scan of leesbare foto) ingevuld via mail naar je promotor. Je promotor bezorgt het aan de juiste dienst voor verdere afhandeling.

Vul luik A aan. Bezorg het formulier aan je promotoren voor de aanvullingen in luik B. Zorg dat het formulier ondertekend en gedateerd wordt door jezelf en je promotoren in luik D en dien het in bij de juiste dienst volgens de afspraken in jouw opleiding.
Zonder dit inschrijvingsformulier krijg je geen toegang tot upload/verdediging van je masterproef.

Please read the information below carefully.

Print this document and complete it by hand writing, using CAPITAL LETTERS.

In times of COVID-19 and during the online courses you send the document (scan or readable photo) by email to your supervisor. Your supervisor delivers the document to the appropriate department.

Fill out part A. Send the form to your supervisors for the additions in part B. Make sure that the form is signed and dated by yourself and your supervisors in part D and submit it to the appropriate department in accordance with the agreements in your study programme.
Without this registration form, you will not have access to the upload/defense of your master's thesis.

LUIK A - VERPLICHT - IN TE VULLEN DOOR DE STUDENT
PART A - MANDATORY - TO BE FILLED OUT BY THE STUDENT

Titel van Masterproef/*Title of Master's thesis:* A PILOT STUDY INVESTIGATING THE CORRELATION BETWEEN THE HEAD REPOSITIONING ACCURACY TASK AND A NEW WEIGHT DISCRIMINATION TASK

● behouden - *keep*

○ wijzigen - *change to:*

/:

O behouden - *keep*

O wijzigen - *change to:*

In geval van samenwerking tussen studenten, naam van de medestudent(en)/*In case of group work, name of fellow student(s):* RICKY VAN HAREN

● behouden - *keep*

O wijzigen - *change to:*

LUIK B - VERPLICHT - IN TE VULLEN DOOR DE PROMOTOR(EN)
PART B - MANDATORY - TO BE FILLED OUT BY THE SUPERVISOR(S)

Wijziging gegevens masterproef in luik A/*Change information Master's thesis in part A:*

O goedgekeurd - *approved*

O goedgekeurd mits wijziging van - *approved if modification of:*

Scriptie/*Thesis:*

O openbaar (beschikbaar in de document server van de universiteit)- *public (available in document server of university)*

O vertrouwelijk (niet beschikbaar in de document server van de universiteit) - *confidential (not available in document server of university)*

Juryverdediging/*Jury Defense:*

De promotor(en) geeft (geven) de student(en) het niet-bindend advies om de bovenvermelde masterproef in de bovenvermelde periode/*The supervisor(s) give(s) the student(s) the non-binding advice:*

O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

O de verdediging is openbaar/*in public*

O de verdediging is niet openbaar/*not in public*

O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK C - OPTIONEEL - IN TE VULLEN DOOR STUDENT, alleen als hij luik B wil overrulen
PART C - OPTIONAL - TO BE FILLED OUT BY THE STUDENT, only if he wants to overrule part B

In tegenstelling tot het niet-bindend advies van de promotor(en) wenst de student de bovenvermelde masterproef in de bovenvermelde periode/*In contrast to the non-binding advice put forward by the supervisor(s), the student wishes:*

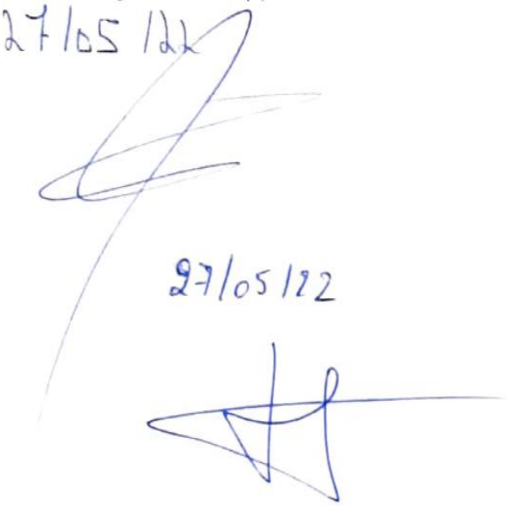
O niet te verdedigen/*not to defend the aforementioned Master's thesis within the aforementioned period of time*

O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK D - VERPLICHT - IN TE VULLEN DOOR DE STUDENT EN DE PROMOTOR(EN)
PART D - MANDATORY - TO BE FILLED OUT BY THE STUDENT AND THE SUPERVISOR(S)

Datum en handtekening student(en)
Date and signature student(s)

27/05/22



Datum en handtekening promotor(en)
Date and signature supervisor(s)

27/05/22

UHASSELT
KNOWLEDGE IN ACTION

Inschrijvingsformulier verdediging masterproef academiejaar 2021-2022,
Registration form jury Master's thesis academic year 2021-2022,

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Faculteit/School: **Faculteit Revalidatiewetenschappen**
Faculty/School: ***Rehabilitation Sciences***

Stamnummer + naam: **1746790 Van Haren Ricky**
Student number + name

Opleiding/*Programme*: **2 ma revalid. & kine musc.**

INSTRUCTIES - *INSTRUCTIONS*

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PART A - MANDATORY - TO BE FILLED OUT BY THE STUDENT

Titel van Masterproef/*Title of Master's thesis:* A PILOT STUDY INVESTIGATING THE CORRELATION BETWEEN THE HEAD ACROSS TIMING ACCURACY TASK AND A NEW WEIGHT DISCRIMINATION TASK

● behouden - *keep*

○ wijzigen - *change to:*

/:

O behouden - *keep*

O wijzigen - *change to:*

In geval van samenwerking tussen studenten, naam van de medestudent(en)/*In case of group work, name of fellow student(s):* MILAN VANDECAETSBEEK

● behouden - *keep*

O wijzigen - *change to:*

LUIK B - VERPLICHT - IN TE VULLEN DOOR DE PROMOTOR(EN)
PART B - MANDATORY - TO BE FILLED OUT BY THE SUPERVISOR(S)

Wijziging gegevens masterproef in luik A/*Change information Master's thesis in part A:*

O goedgekeurd - *approved*

O goedgekeurd mits wijziging van - *approved if modification of:*

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O de verdediging is niet openbaar/*not in public*

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O te verdedigen/*to defend the aforementioned Master's thesis within the aforementioned period of time*

LUIK D - VERPLICHT - IN TE VULLEN DOOR DE STUDENT EN DE PROMOTOR(EN)
PART D - MANDATORY - TO BE FILLED OUT BY THE STUDENT AND THE SUPERVISOR(S)

Datum en handtekening student(en)
Date and signature student(s)

27/05/22

Datum en handtekening promotor(en)
Date and signature supervisor(s)

27/05/2022

Akkoord indiening MP

Inbox ×

Katleen BOGAERTS
aan mij, Ricky, Vicky, Indra

za 28 mei 06:03 (8 dagen geleden)

Beste Ricky en Milan,

Via deze mail geef ik akkoord voor verdediging van jullie MP2 in eerste zit. Veel succes!

Hartelijke groeten.

Katleen Bogaerts

--

Prof. Dr. Katleen Bogaerts
Assistant Professor
REVAL - Rehabilitation Sciences and Physiotherapy
Faculty of Rehabilitation Sciences

T +32(0)11 26 93 62

Bereikbaar op maandag, dinsdag en vrijdag

www.uhasselt.be
Universiteit Hasselt - Campus Diepenbeek
Agoralaan Gebouw D - B-3590 Diepenbeek
Kantoor BMO-A0.02

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