UHASSELT

KNOWLEDGE IN ACTION

Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Can canalith repositioning maneuvers improve the postural balance and fear of falling in older adults with benign paroxysmal positional vertigo?

Lieselotte Langens
Joke Vanherk

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

PROMOTOR :

Prof. dr. Joke SPILDOOREN

BEGELEIDER :

Mevrouw Sara PAUWELS

2021
2022

UHASSELT

KNOWLEDGE IN ACTION

www.uhasselt.be
Universiteit Hasselt
Campus Hasselt:
Martelarenlaan 42 | 3500 Hasselt
Campus Diepenbeek:
Agoralaan Gebouw D | 3590 Diepenbeek

UHASSELT

KNOWLEDGE IN ACTION

Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Can canalith repositioning maneuvers improve the postural balance and fear of falling in older adults with benign paroxysmal positional vertigo?

Lieselotte Langens
Joke Vanherk

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

PROMOTOR :

Prof. dr. Joke SPILDOOREN

BEGELEIDER :

Mevrouw Sara PAUWELS

ACKNOWLEDGEMENT

First, our deepest gratitude goes to our promotor Prof. Dr. Spildooren Joke and supervisor Pauwels Sara who guided us through our master's thesis. They contributed much by giving advice and feedback. Pauwels Sara also recruited and assessed the participants and executed the interventions.

In addition, we want to thank the staff of the vestibular department of Ziekenhuis Oost-Limburg (ZOL) for giving permission to use their equipment and accommodation for the measurements and treatments. They also helped with the recruitment of participants for this study.

Lastly, we want to thank the participants that took part in this study.

Peer, 28/05/2022 L.L.

Hechtel, 28/05/2022 V.J.

RESEARCH CONTEXT

This master's thesis is part of the research field of geriatric rehabilitation, particularly vestibular disorders. This is a duo master's thesis conducted by Langens Lieselotte and Vanherk Joke under supervision of Prof. Dr. Spildooren Joke and Pauwels Sara. It is an isolated study.

People with benign paroxysmal positional vertigo (BPPV) often encounter imbalance during and between vertigo episodes (Bhattacharyya et al., 2017). Sensory orientation, especially during conditions with altered or no visual and proprioceptive input, and postural stability during tandem walk are significantly decreased in patients suffering from BPPV (Celebisoy, Bayam, Güleç, Köse, & Akyürekli, 2009; Chang, Hsu, Yang, &e Wang, 2006). These balance problems can lead to an increase in fall risk, fall-related injuries, fear of falling and a reduction in quality of life (Fernández, Breinbauer, & Delano, 2015). Fear of falling can result in increased avoidance behaviour and decreased confidence, leading to an even greater risk of falling (Reelick, van Iersel, Kessels, & Rikkert, 2009). Older adults with BPPV often report less vertigo and more balance problems than younger patients with BPPV (Fernández et al., 2015). Previous literature showed that canalith repositioning maneuvers (CRM) significantly improve vertigo, nystagmus, sensory orientation, experienced disability and quality of life (Blatt, Georgakakis, Herdman, Clendaniel, & Tusa, 2000). They also improve postural sway during stance and postural sway during unipedal stance with eyes closed (Chang, Yang, Hsu, Chern, & Wang, 2008; Cohen-Shwartz, Nechemya, & Kalron, 2020; Giacomini, Alessandrini, & Magrini, 2002). However, CRM seem to be less effective in reducing dizziness-related handicap and lead to a higher recurrence rate in older adults compared to younger adults (Batuecas-Caletrio et al., 2013; Laurent et al., 2022; Sim, Tan, & Hill, 2019).

Despite the growing interest in CRM for treating BPPV, there is little evidence about the efficacy of CRM on postural control in older adults with BPPV. This study will focus on investigating the effectiveness of CRM on postural control in older adults with BPPV, taking all six underlying mechanisms of balance as stated by Horak et al. into account. The effect of CRM on fear of falling in older adults with BPPV was also examined.

The research domain of this master's thesis, namely 'balance problems in older adults with BPPV' was determined by our supervisor Pauwels Sara. The research question 'What is the treatment efficiency of canalith repositioning maneuvers on postural control and fear of falling in older adults with benign paroxysmal positional vertigo?' was determined by L.L. and V.J. The research protocol was defined and executed by Pauwels Sara. The data acquisition was also performed by her, with the help of L.L., V.J. and master students. Data analysis and writing of this thesis were carried out by L.L and V.J.

REFERENCES

Batuecas-Caletrio, A., Trinidad-Ruiz, G., Zschaeck, C., del Pozo de Dios, J. C., de Toro Gil, L., Martin-Sanchez, V., & Martin-Sanz, E. (2013). Benign paroxysmal positional vertigo in the elderly. *Gerontology, 59*(5), 408-412. doi:10.1159/000351204

Bhattacharyya, N., Gubbels, S. P., Schwartz, S. R., Edlow, J. A., El-Kashlan, H., Fife, T., . . . Corrigan, M. D. (2017). Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update). *Otolaryngol Head Neck Surg, 156*(3_suppl), S1-s47. doi:10.1177/0194599816689667

Blatt, P. J., Georgakakis, G. A., Herdman, S. J., Clendaniel, R. A., & Tusa, R. J. (2000). The effect of the canalith repositioning maneuver on resolving postural instability in patients with benign paroxysmal positional vertigo. *Am J Otol, 21*(3), 356-363. doi:10.1016/s0196-0709(00)80045-9

Celebisoy, N., Bayam, E., Güleç, F., Köse, T., & Akyürekli, O. (2009). Balance in posterior and horizontal canal type benign paroxysmal positional vertigo before and after canalith repositioning maneuvers. *Gait Posture, 29*(3), 520-523. doi:10.1016/j.gaitpost.2008.12.002

Chang, W. C., Hsu, L. C., Yang, Y. R., & Wang, R. Y. (2006). Balance ability in patients with benign paroxysmal positional vertigo. *Otolaryngol Head Neck Surg, 135*(4), 534-540. doi:10.1016/j.otohns.2005.10.001

Chang, W. C., Yang, Y. R., Hsu, L. C., Chern, C. M., & Wang, R. Y. (2008). Balance improvement in patients with benign paroxysmal positional vertigo. Clin Rehabil, 22(4), 338-347. doi:10.1177/0269215507082741

Cohen-Shwartz, Y., Nechemya, Y., & Kalron, A. (2020). Canalith repositioning procedure improves gait and static balance in people with posterior semicircular canal benign paroxysmal positional vertigo. *J Vestib Res, 30*(5), 335-343. doi:10.3233/ves-200713

Fernández, L., Breinbauer, H. A., & Delano, P. H. (2015). Vertigo and Dizziness in the Elderly. *Front Neurol, 6*, 144. doi:10.3389/fneur.2015.00144

Giacomini, P. G., Alessandrini, M., & Magrini, A. (2002). Long-term postural abnormalities in benign paroxysmal positional vertigo. *ORL J Otorhinolaryngol Relat Spec, 64*(4), 237-241. doi:10.1159/000064130

Horak, F. B., Wrisley, D. M., & Frank, J. (2009). The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Phys Ther, 89*(5), 484-498. doi:10.2522/ptj.20080071

Laurent, G., Vereeck, L., Verbecque, E., Herssens, N., Casters, L., & Spildooren, J. (2022). Effect of age on treatment outcomes in benign paroxysmal positional vertigo: A systematic review. *J Am Geriatr Soc, 70*(1), 281-293. doi:10.1111/jgs.17485

Reelick, M. F., van Iersel, M. B., Kessels, R. P., & Rikkert, M. G. (2009). The influence of fear of falling on gait and balance in older people. *Age Ageing, 38*(4), 435-440. doi:10.1093/ageing/afp066

Sim, E., Tan, D., & Hill, K. (2019). Poor Treatment Outcomes Following Repositioning Maneuvers in Younger and Older Adults With Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis. J A*m Med Dir Assoc, 20*(2), 224.e221-224.e223. doi:10.1016/j.jamda.2018.11.019

Can canalith repositioning maneuvers improve the postural balance and fear of falling in older adults with benign paroxysmal positional vertigo?

What is the treatment efficiency of repositioning maneuvers on postural control and fear of falling in older adults with benign paroxysmal positional vertigo?

Langens Lieselotte
Vanherk Joke
Promotor: Prof. Dr. Spildooren Joke
Supervisor: Pauwels Sara

TABLE OF CONTENT

1. Abstract

Background: Literature showed the effectiveness of canalith repositioning maneuvers (CRM) to improve the reduced postural stability in middle-aged adults with benign paroxysmal positional vertigo (BPPV). However, the effect of CRM on postural balance and fear of falling in older adults with BPPV is unclear.

Objectives: This single-group study investigated the effect of CRM on postural control and fear of falling in older adults with BPPV.

Participants: Eleven older adults, with an average age of 73 years, diagnosed with posterior or lateral semicircular canal BPPV were included and were recruited from Ziekenhuis Oost-Limburg.

Intervention: All participants received a CRM specific for their type of BPPV, after a diagnostic maneuver was performed. The re-evaluation and treatment were repeated weekly until vertigo and/or nystagmus disappeared.

Measurements: The Mini Balance Evaluation System test, Clinical Test of Sensory Interaction on Balance, Ten-Meter Walk Test, Timed Chair-Stand Test and Falls Efficacy Scale were performed before the start of the treatment (baseline), one month after baseline and three months after baseline. APDM sensors were used during every test.

Results: The centre of pressure path length while standing on a foam with eyes closed significantly decreased one month after baseline (p-value= 0.008) and this difference remained three months after baseline (p-value= 0.013). Statistical analysis revealed no significant within-subject effect for the remaining outcome measures.

Conclusion: Canalith repositioning maneuvers are effective to improve sensory orientation while standing on a foam with eyes closed after one month, with a remaining effect after three months in older adults with BPPV. CRM might not be effective in improving the other balance mechanisms (the biomechanical system, anticipatory postural adjustments, reactive postural responses, and stability in gait) and fear of falling. Future randomized controlled trials are needed to confirm these findings.

Keywords: *Benign paroxysmal positional vertigo, older adults, canalith repositioning maneuvers, balance, fear of falling*

2. Introduction

Benign Paroxysmal Positional Vertigo (BPPV) is the most common disorder of the peripheral vestibular system and has a life-time prevalence of 2.4%, primarily affecting women and older adults. The prevalence of this condition is positively correlated with age, as the one-year prevalence shows a seven-fold increase in adults over 60 years compared to adults under 40 (von Brevern et al., 2007). BPPV is caused by a displacement of otoconia originating from the utricular macula. Due to head movements, detached otoconia either circulate freely in the endolymph of one of the semicircular canals (canalithiasis) or adhere to the cupula and cause it to be deformed (cupulolithiasis). This typically results in episodes of sudden rotatory dizziness (vertigo) and repetitive uncontrolled eye movements (nystagmus) (Hall, Ruby, & McClure, 1979). The episodes usually last less than one minute and are often accompanied by nausea and imbalance (Rodrigues, Ledesma, de Oliveira, & Bahamad Júnior, 2018). As a result of their anatomical positions, BPPV of the posterior semicircular canal is more common than BPPV of the horizontal or anterior semicircular canal and accounts for more than 85% of all cases (Bhattacharyya et al., 2017).

According to Horak et al. balance consists of six different underlying systems; the biomechanical system, anticipatory postural adjustments (APA's), stability limits, reactive postural responses, sensory orientation, and stability in gait. All six mechanisms are important for keeping balance in daily life. For example, the inability to react with postural responses to perturbations is a critical factor in increasing fall risk (Maki & McIlroy, 1997). An impairment of the vestibular system can lead to balance problems such as impaired body righting reactions and increased body sway, indicating that at least one of the balance mechanisms is compromised (Szturm, Reimer, & Hochman, 2015). Fifty percent of the patients diagnosed with BPPV complain of imbalance during and between vertigo episodes (Bhattacharyya et al., 2017). Literature states that sensory orientation, especially during situations that lack visual and proprioceptive input, and postural stability during tandem walk are impaired in patients with BPPV (Celebisoy, Bayam, Güleç, Köse, & Akyürekli, 2009; Chang, Hsu, Yang, & Wang, 2006). Due to this imbalance, patients suffering from BPPV have an increase in fall risk and fall-related injuries, which can lead to an increased fear of falling and a reduction in quality of life (Fernández, Breinbauer, & Delano, 2015). Similar to BPPV, fear of falling is reported more

in women and increases with age (Schlick et al., 2016). Fear can cause an increase in avoidance behaviours and decreased confidence in the ability to maintain balance, leading to an even higher fall risk in the future (Reelick et al., 2009). Therefore, it is clear that balance impairments in patients with BPPV need to be managed.

Diagnosis of BPPV is based on the experienced symptoms and induced nystagmus and vertigo using provocation tests such as the Dix-Hallpike maneuver or supine-roll test. BPPV resolves spontaneously in 20% of the cases within one month and in almost 50% within three months. In the remaining cases, canalith repositioning maneuvers (CRM) like the Epley maneuver, Gufoni maneuver or Sémont's liberatory maneuver are needed to return the displaced otoconia (Bhattacharyya et al., 2017). Previous literature showed that canalith repositioning maneuvers (CRM) significantly improve vertigo, nystagmus, sensory orientation, experienced disability, and quality of life (Blatt, Georgakakis, Herdman, Clendaniel, & Tusa, 2000). They also improve postural sway during stance and postural sway during unipedal stance with eyes closed (Chang, Yang, Hsu, Chern, & Wang, 2008; Cohen-Shwartz, Nechemya, & Kalron, 2020; Giacomini, Alessandrini, & Magrini, 2002). However, the recurrence rate of BPPV after treatment with CRM is around 36% and some patients report residual postural instability, dizziness, and anxiety regardless of a negative diagnostic maneuver (Abou-Elew et al., 2010; Hilton & Pinder, 2014; Luryi et al., 2018). Older adults often report less vertigo and more balance problems compared to younger patients, which can complicate the diagnosis of BPPV (Fernández et al., 2015). CRM can also be performed in older adults, but they seem to be less effective in reducing dizziness-related handicap and lead to a higher recurrence rate compared to younger adults (Batuecas-Caletrio et al., 2013; Laurent et al., 2022; Sim, Tan, & Hill, 2019).

Despite the growing interest in CRM for treating BPPV, there is little evidence about the efficacy of CRM on postural balance in older adults with BPPV. Additionally, most of the studies interested in balance problems in patients with BPPV investigated possible constraints on sensory orientation. However, there is little evidence investigating all six underlying mechanisms of balance. Therefore, the aim of this study is to investigate the treatment efficiency of canalith repositioning maneuvers on postural control in older adults with BPPV, taking all six underlying mechanisms of balance as stated by Horak et al. into account. The effect of CRM on fear of falling in older adults with BPPV was also examined.

3. Method

3.1 Design

This single group pre-post study was conducted from September 2021 until May 2022 and has been carried out by Sara Pauwels at the vestibular department of Ziekenhuis Oost-Limburg (ZOL) Genk. All BPPV participants were assigned to one intervention group (canalith repositioning maneuvers), there was no control group included. At baseline (M1), after the participants gave informed consent, outcome measures and demographic characteristics were documented and evaluated by a certified physiotherapist and master students from the faculty of Rehabilitation Sciences of the university of Hasselt. Afterwards, all participants were treated with a canalith repositioning maneuver specific for their type of BPPV. Treatment was repeated weekly until the positioning nystagmus disappeared. The presence of BPPV was re-evaluated by diagnostic maneuvers before every treatment session. The outcome measures were documented again one month (M2) and three months (M3) after baseline measurement.

Figure 1. *An overview of the study design*

Abbreviations: *CRM= canalith repositioning maneuvers, M= measurement moment*
Note: *M1: baseline measurement, M2: one month after M1, M3: three months after M1*

3.2 Participants

Community-dwelling older adults diagnosed with BPPV were recruited at the vestibular department of ZOL Genk. Inclusion criteria were: (1) aged 65 years or older; (2) diagnosed with either canalithiasis or cupulolithiasis of the posterior and/or lateral semicircular canal BPPV according to the Dix-Hallpike maneuver and supine roll test; (3) able to stand independently for at least 30 seconds; (4) able to walk with or without a walking aid for at least 10 meters; (5) Dutch speaking. Exclusion criteria were: (1) diagnosed with evolutionary disorders of the central nervous system (e.g. multiple sclerosis, Parkinson's disease, amyotrophic lateral sclerosis); (2) contra-indications for the diagnostic maneuvers (e.g. severe limitation in mobility of the cervical spine); (3) temporarily or permanently living in a residential or psychiatric care centre, a home for the disabled or rehabilitation centre; (4) inability to understand and follow simple instructions (e.g. due to severe dementia, hearing loss or visual impairment); (5) taking antivertigo drugs; (5) being in the rehabilitation phase after an orthopaedic or cardiovascular incident.

The Dix-Hallpike maneuver and the supine roll test were performed to diagnose posterior and lateral semicircular canal BPPV respectively. The possible presence of nystagmus was examined using videonystagmography. If the Dix-Hallpike maneuver causes a torsional upbeating nystagmus towards the affected ear, posterior semicircular canal BPPV is diagnosed. Lateral semicircular canal BPPV was diagnosed using the supine roll test.

All participants signed the informed consent at the beginning of the first measurement moment. The Medical Ethics Committees of the University of Hasselt and Ziekenhuis Oost-Limburg approved this study on May 31st, 2021 (approval code: B3712021000013 an clinical trial registration: B3712021000013).

3.3 Procedure

Intervention procedure

At the start of every treatment session, a diagnostic maneuver was performed to (re-)evaluate the presence of BPPV. The treatment consisted of a canalith repositioning maneuver specific for the patient's type of BPPV, followed by a re-evaluation of the presence of BPPV after a maximum of ten minutes. In case of posterior canal BPPV, a second CRM during the same session was performed if BPPV was still present and if tolerated by the patient. The re-evaluation and treatment were repeated weekly until the vertigo and/or positioning nystagmus disappeared. The number of treatment sessions was noted for each patient. The treatment was performed by a certified physiotherapist or the vestibular staff of the hospital.

Posterior semicircular canal BPPV:

The Epley maneuver was used to treat canalithiasis of the posterior semicircular canal. The maneuver starts with the patient in long sit. Afterwards, five different actions are performed: (1) the therapist turns the head 45° towards the affected side; (2) the patient is passively moved in a supine position with the head in 30° extension, while the head is kept in 45° rotation; (3) the therapist rotates the head 90° to the non-affected side, while maintaining extension of the head; (4) the therapist rotates the head again 90° to the non-affected side and the patient actively rotates his/her body in the same direction until lying on the non-affected side, facing the table; (5) patient is moved to a sitting position. During every position the eyes are observed by the therapist and every position is held for one minute or until nystagmus is gone. The patient may not close their eyes or fixate on a point in space.

When cupulolithiasis of the posterior semicircular canal was present or if patients with canalithiasis of the posterior semicircular canal were unable to execute the Epley maneuver, the Sémont maneuver was performed. During this maneuver, the patient starts in a sitting position on the side of the table. Forty-five degrees rotation of the head towards the non-affected ear is passively induced by the therapist and then the patient is brought into a side-

lying position on the affected side. The patient is now looking up. This position is held until nystagmus and/or vertigo disappears. Afterwards, the patient is quickly swung 180° to the opposite side while keeping the head in the same position. The nose of the patient is now pointing to the table. This position is also held until symptoms disappear.

Lateral semicircular canal BPPV (geotropic variant):

Patients with geotropic lateral canal BPPV were treated with the Gufoni maneuver. During this maneuver, the patient sits on the side of the table. The head is kept straight while the patient is quickly brought to a side-lying position on the unaffected side. Afterwards, a 45° downward rotation of the head is induced by the therapist, resulting in the patient facing the table. This position is held for one to two minutes or until the nystagmus disappears, before returning to an upright sitting position while the head is kept in the downward rotated position. The head is turned straight once the patient is sitting upright.

Lateral semicircular canal BPPV (apogeotropic variant):

The modified Gufoni maneuver was used to treat apogeotropic lateral canal BPPV. The patient is sitting on the table facing the therapist and is rapidly moved to the affected side, while maintaining the position of the head. This position is held for 30 seconds and afterwards the head is rotated 45° upwards, with the nose pointing to the ceiling. The patient returns actively to sitting position after one to two minutes or when the nystagmus has disappeared, while the head is kept in the same position. When back in the sitting position, the head is turned to a normal position.

Outcome measures

The outcome measures were measured at baseline, one month and three months after baseline. The measurement scales that were used are the Mini Balance Evaluation System test (Mini BESTest), the Clinical Test of Sensory Interaction on Balance (CTSIB), the Ten-Meter Walk Test (10MWT), the Timed Chair-Stand Test and the Falls Efficacy Scale (FES-I). APDM three axis wearable inertial sensors (Opals and Mobility Lab, 2007) were used during every outcome measurement, except for FES-I. Four wireless inertial sensors were attached on each participant with elastic straps. One lumbar sensor, one chest sensor and two-foot sensors were used. All measurements were performed by a certified physiotherapist and master students from the faculty of Rehabilitation Sciences of the university of Hasselt. Additionally, the demographic characteristics (age, sex, cognition, living condition, nationality, use of walking aids and comorbidities) of the participants were documented at baseline. The cognitive ability of the participants was measured using the Montreal Cognitive Assessment (MOCA).

Mini Balance Evaluation System test (Mini BESTest):

The Mini Balance Evaluation System test (Mini BESTest) is a shortened version of the Balance Evaluation Systems Test (BESTest). The BESTest assesses postural balance using 36 items and is divided in six subcategories according to the six different underlying systems according to Horak et al.; constraints on the biomechanical system, stability limits and verticality, anticipatory postural adjustments (APA's), reactive postural responses, sensory orientation, and stability in gait.

Biomechanical constraints during stance are imposed by the base of support provided by the feet, postural alignment, the strength of the ankle and hip, and the potential to rise from sitting on the floor to stance. A person's *stability limits* refer to the distances this person can move their body in any direction without changing their base of support. APA's are active movements of the body's centre of mass during tasks, in anticipation of a postural transition from one body position to another. *Reactive postural responses* include both in-place and compensatory stepping responses to an external perturbation. *Sensory orientation* is

provided by the efficient integration of the somatosensory, visual, and vestibular system and identifies changes in body sway during stance associated with altering visual or somatosensory information for controlling standing balance. *The stability during gait* is the ability to maintain balance during gait while changing gait speed or performing double tasks (Horak et al., 2009).

The Mini BESTest consists of fourteen tasks divided in four subcategories: anticipatory postural adjustments (APA's), reactive postural responses, sensory orientation, and stability in gait. Items that measure the anticipatory postural adjustments capacity are: (1) sit to stand, (2) rise to toes and (3) stand on one leg. Reactive postural responses are measured using; (4) forward compensatory stepping correction, (5) backward compensatory stepping correction and (6) lateral compensatory stepping correction. Sensory orientation is tested with; (7) stance with feet together and eyes open on a firm surface, (8) stance with feet together on a foam surface and (9) stance on an inclined platform with eyes closed. Lastly, items that measure the dynamic gait are: (10) changing the gait speed, (11) horizontal head turns while walking, (12) pivot turns while walking, (13) stepping over obstacles and (14) Timed up and go (standing up from a chair, walking three metres, turn around, walking back and return to sitting). Each item receives a score from zero to two points and the test has a maximum score of 28 points. A total score below nineteen points indicates an increased fall risk (Horak et al., 2009). The Mini BESTest shows a good interrater reliability (ICC= 0,71) and test-retest reliability (ICC= 0,73) in older people living in the community. This is similar to the original BESTest (ICC = 0,86 and ICC= 0,77) (Marques et al.,2016).

Clinical Test of Sensory Interaction on Balance (CTSIB):

The Clinical Test of Sensory Interaction on Balance (CTSIB) measures the sensory contribution to postural control during six balancing conditions. Patients are asked to maintain their balance while: (1) standing on a firm surface with eyes open, (2) standing on a firm surface with eyes closed, (3) standing on a firm surface with a visual conflict dome, (4) standing on a foam with eyes open, (5) standing on a foam with eyes closed and (6) standing on a foam with a visual conflict dome (Figure 2). Patients must perform all conditions during 30 seconds with their hands on their hips. A condition is failed if the position of the arms or feet changes during the 30 second's trial. Impairment of the vestibular system typically causes an increased postural sway during condition five and six (Shumway-Cook & Horak, 1986). Conditions one and five were already measured during the Mini BESTest and were therefore not repeated during this test. CTSIB measures sensory orientation, which is one of the six mechanisms of balance according to Horak et al.

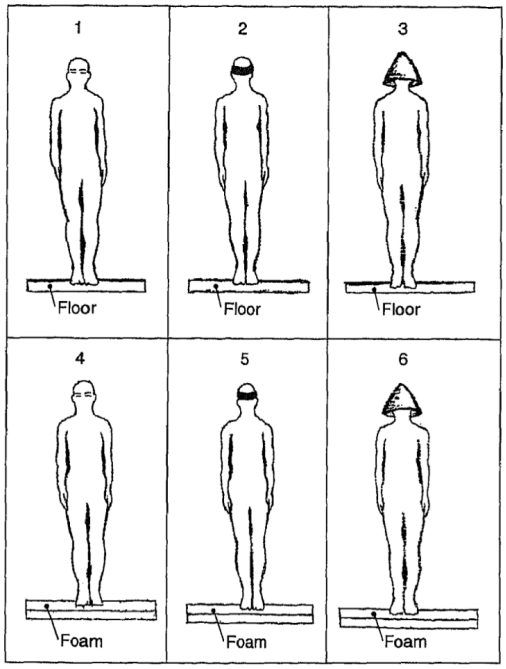


Figure 2. *Testing conditions for the Clinical Test of Sensory Interaction on Balance (Shumway-Cook & Horak, 1986).*

Ten-Meter Walk Test (10MWT):

The assessment of the walking speed and walking performance was performed using the Ten-Meter Walk Test (10MWT). During this test, the patient is asked to walk a distance of ten meters twice. This is done at their comfortable walking speed and, if necessary, with an assistive device (Collen, Wade, & Bradshaw, 1990). The participants were not assisted, but the therapist walked close to the participant to ensure safety.

Timed Chair-Stand Test:

The Timed Chair-Stand Test assesses the lower limb strength and therefore measures the potential constraints on the biomechanical system, which is one of the six of the underlying mechanisms of balance according to Horak et al. During this test, the patient starts in a sitting position on a chair (height: 43-45cm), with the arms crossed in front of the chest, and is asked to rise five times without using the arms. The total performance time is measured during the test. The therapist stays close to the patient and the chair is placed against a wall for safety reasons (Csuka & McCarty, 1985).

Falls Efficacy Scale International (FES-I):

The assessment of fear of falling was measured with the Falls Efficacy Scale International. This sixteen-item questionnaire collects information about the subjective level of fear of falling during certain daily activities (Yardley et al., 2005). For example, the possibility of falling while cleaning the house, getting dressed, going up the stairs and walking in a crowded place. Each item is scored on a four-point Likert scale, with (1) not concerned at all, (2) somewhat concerned, (3) fairly concerned and (4) very concerned. A higher total score indicates a higher level of concern.

3.4 Data-analysis

Data-analysis was performed using IBM SPSS statistics 26 (Armonk, 2019). The significance level was set at 0.05 and evaluated using two-tailed tests. For the demographic data, descriptive statistics were used. Normality of the data distribution was assessed with the Shapiro-Wilk test. In case of a normal distribution, repeated measures ANOVA was used to evaluate the effect of CRM over time (baseline, after one month and three months follow-up). In case of a non-normal distribution, the Friedman test was used. If there was a statistical difference, the Wilcoxon signed rank test was used for pairwise comparisons. The Cochran's Q Test was used when discrete variables were analysed.

4. Results

4.1 Outcome demographic characteristics

At the end of the study, eleven participants were included (Appendix 1). One participant was excluded before the third measurement moment due to not wanting to participate anymore for fear of COVID-19. The group consisted of five males and six females, with an average age of 72.64 years. The majority (63.6%) of the participants were diagnosed with right posterior canal BPPV. An average of 1.46 therapy sessions were needed to treat BPPV. The MOCA was used to evaluate the cognitive function of the participants, resulting in a mean total score of 22.73 points. This average of the MOCA test is in line with the normative data in the literature (Rossetti, Lacritz, Cullum, & Weiner, 2011; Sachs et al., 2021). Only 36.4% had a normal cognitive function according to the cut-off score of 26 points proposed by Nasreddine et al. 81.8% of the participants were Belgian, while the remaining participants were Dutch and Italian. Seven of the eleven participants still lived with their partner and only one participant used a walking aid, namely a four-wheel walker. This participant used no walking aid during the measurements. All participants had at least one comorbidity. An overview of the demographic characteristics is given in Table 1.

Table 1. *Demographic data of the participants*

Characteristic	N	%	Mean (SD)	Range
Sex (male/female)	5/6	45.5%/54.5%		
Age (years)			72.64 (3.50)	65-78
Type of BPPV				
Right posterior SCC	7	63.6%		
Left posterior SCC	2	18.2%		
Right lateral SCC	1	9.1%		
Left lateral SCC	1	9.1%		
Number of treatment sessions needed			1.46 (1.22)	0-4
MOCA (total score)			22.73 (4.03)	16.00-29.00
normal cognition (total score≥26)	4	36.4%		
Living situation (alone/ with partner)	4/7	36.4%/ 63.6%		
Use of walking aid (no/yes)	10/1	90.9%/ 9.1%		
Comorbidities				
Cardiovascular	2	18.2%		
Cerebrovascular	1	9.1%		
Diabetes	1	9.1%		
Hypertension	6	54.5%		
Hypotension	1	9.1%		
Hypercholesterolemia	5	45.5%		
Vitamin D insufficiencies	2	18.2%		
Osteoporosis	2	18.2%		
Other	6	54.5%		

Abbreviations: *SCC= semicircular canal, n= number, %: percentage, SD= standard deviation, MOCA= Montreal cognitive assessment, m= meter, kg= kilogram*

4.2 Outcome measurements

Effect of CRM on the CTSIB

Significant differences between the proportions of people completing or not completing a condition of the CTSIB were measured using the Cochran's Q Test (Table 2). Completing a condition means that the participant maintained the position of the arms and feet for 30 seconds or more during this condition. The analysis revealed that there were no statistically significant differences between the proportions over time for any condition.

Through the use of APDM sensors the acceleration mean velocity and centre of pressure (COP) path length were analysed for each condition of the CTSIB. The COP path length during every condition was divided by the duration of the condition for each participant to normalise the data. For the first, the second and the fourth condition the Friedman test was used because of a non-normal distribution of the acceleration mean velocity and the COP path length. The Friedman test was also used for the analysis of the COP path length of the third and sixth condition. The other parameters were analysed using repeated measures ANOVA. Statistical analysis revealed a significant within-subject effect over time for COP path length during stance on a foam with eyes closed (p-value= 0.011) (Table 2). This indicates that there is a significant difference between one of the three timepoints for the COP path length during this condition. Pairwise comparisons showed that there is a significant difference of the COP path length between baseline and after one month (p-value= 0.008), and between baseline and after three months (p-value= 0.013) (Figure 3). For the acceleration mean velocity there was no significant difference over time for each condition of the CTSIB.

Table 2. *Data of CTSIB*

Test	Variable	Baseline	1 month follow-up Mean (SD)	3 months follow-up	P
Condition 1: Eyes open + firm surface	Duration				
	Completed 30 sec. (n)	11	11	11	1.000
	Acc. mean velocity (m/sec.)	0.13 (0.07)	0.15 (0.96)	0.13 (0.08)	0.529
	Path length (m/sec.)	0.21 (0.06)	0.23 (0.18)	0.18 (0.05)	0.761
Condition 2: Visual dome + firm surface	Duration				
	Completed 30 sec. (n)	11	11	11	1.000
	Acc. mean velocity (m/sec.)	0.20 (0.13)	0.14 (0.09)	0.15 (0.12)	0.234
	Path length (m/sec.)	0.27 (0.10)	0.22 (0.05)	0.23 (0.09)	0.086
Condition 3: Eyes closed + firm surface	Duration				
	Completed 30 sec. (n)	10	11	11	0.368
	Acc. mean velocity (m/sec.)	0.16 (0.08)	0.17 (0.08)	0.16 (0.07)	0.910
	Path length (m/sec.)	0.59 (0.91)	0.22 (0.05)	0.28 (0.11)	0.086
Condition 4: Eyes open + foam	Duration				
	Completed 30 sec. (n)	10	11	11	0.368
	Acc. mean velocity (m/sec.)	0.18 (0.07)	0.19 (0.09)	0.19 (0.08)	0.913
	Path length (m/sec.)	0.57 (0.88)	0.25 (0.07)	0.27 (0.06)	0.178
Condition 5: Visual dome + foam	Duration				
	Completed 30 sec. (n)	8	11	9	0.174
	Acc. mean velocity (m/sec.)	0.21 (0.11)	0.30 (0.18)	0.30 (0.14)	0.212
	Path length (m/sec.)	1.55 (2.49)	0.61 (0.21)	0.84 (0.80)	0.761
Condition 6: Eyes closed + foam	Duration				
	Completed 30 sec. (n)	8	11	11	0.051
	Acc. mean velocity (m/sec.)	0.31 (0.12)	0.25 (0.16)	0.23 (0.11)	0.158
	Path length (m/sec.)	1.37 (1.61)	0.54 (0.18)	0.59 (0.17)	0.011*

Abbreviations: *n= number, acc.= acceleration, m= meter, sec.= seconds, SD= standard deviation, P= p-value, *= p-value significant <0.05*

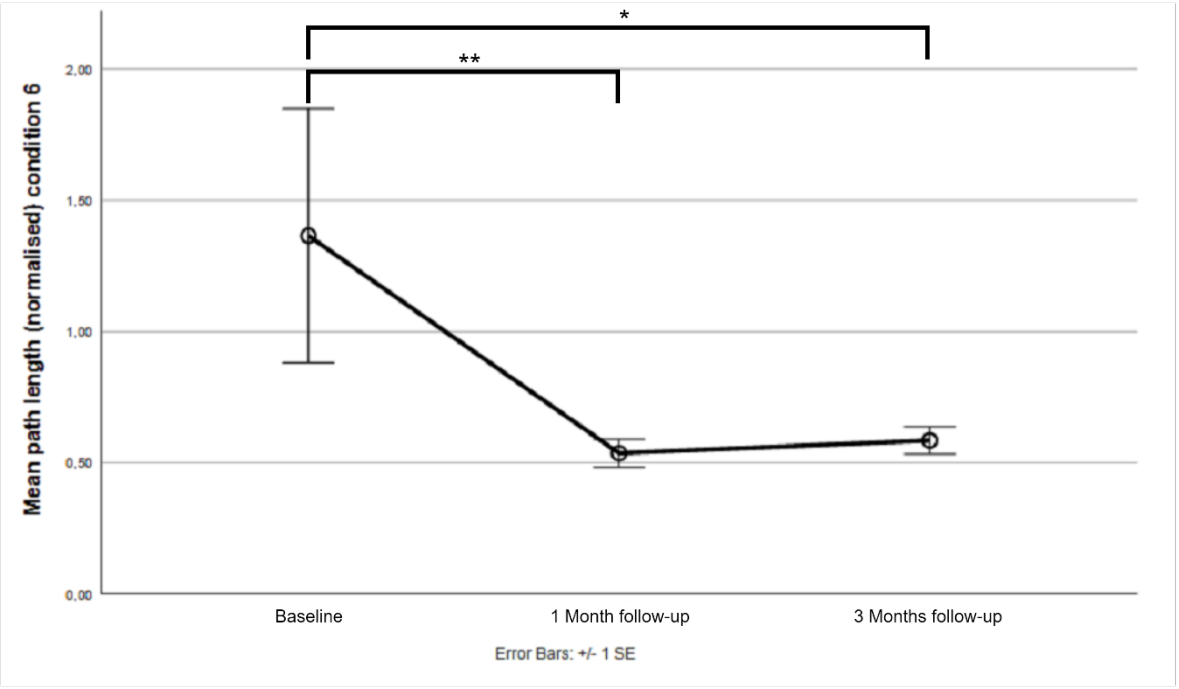


Figure 3. *Pairwise comparisons of mean path length (normalised) during condition 6 'eyes closed and foam' of the CTSIB*

Abbreviations: **= p-value significant <0.05, **= p-value significant <0.01, SE= standard error*

Effect of CRM on the Mini BESTest:

Due to non-normal distributions, the Friedman test was executed on the total score and every subscore of the Mini BESTest, except the subscore 'stability in gait' which was analysed using the repeated measures ANOVA. Statistical analysis revealed no significant within-subject effect over time for the total scores and the four subscores on the Mini BESTest (Table 4). This indicates that there is no significant difference on the Mini BESTest between evaluation at baseline, after one month and after three months.

Effect of CRM on Timed up and go with(out) double task:

The Timed up and go (TUG) with and without double task are two test items included in the Mini BESTest. Using APDM sensors, extra parameters were yielded besides the total score and subscores of the Mini BESTest. The total duration, duration of sit to stance and the duration of stance to sit of these two test items were analysed. Except for the total duration of the TUG with double task, which was analysed with the Friedman test, repeated measures

ANOVA was used for the statistical analysis of the parameters. There were no significant differences between the three timepoints for each parameter of the Timed up and go with and without double task (Table 4).

Effect of CRM on unipedal stance:

The Mini BESTest consists of two items that measure the patient's ability to stand on one leg. The patient gets a normal score for the test item if they can stand on one leg for at least 20 seconds. During the Mini BESTest each leg is tested twice, and the best attempt of each leg is scored. The duration, acceleration mean velocity and path length of the best attempt of each leg were obtained using APDM sensors. The COP path length of each leg was divided by the seconds performed during this test for each participant to normalise the data. The acceleration mean velocity of the left leg was analysed with repeated measures ANOVA. Statistical analysis of the other parameters was performed using the Friedman test. There were no significant differences between the different timepoints for each parameter of the right and left leg (Table 4).

Effect of CRM on the Timed Chair-Stand Test:

The total duration, duration from sit to stance and the duration from stance to sit were measured by APDM sensors during the Timed Chair-Stand Test. The Friedman test was used to analyse the duration from sit to stance. The other parameters were analysed using repeated measures ANOVA. Statistical analysis revealed no significant within-subject effect over time for each parameter (Table 4).

Effect of CRM on the Ten-Meter Walk Test:

Through the use of APDM sensors the cadence and gait speed of each leg was measured during the Ten-Meter Walk Test. Repeated measures ANOVA was executed on every parameter. There is no significant difference on each parameter for each leg at baseline, after one month and after three months (Table 4).

Effect of CRM on the Falls Efficacy Scale:

Because normality of the total score on the Falls Efficacy Scale (FES-I) was not met, the Friedman test was used to analyse the results. This showed no significant difference between the three timepoints on the total score on the FES-I (Table 4).

Table 4. *Data of outcome measurements*

Test	Variable	Baseline	1 month follow-up	3 months follow-up	P
			Mean (SD)		
Mini BESTest	Total score (points)	21.64 (3.98)	23.91 (2.51)	23.82 (2.79)	0.226
	Score anticipatory postural adjustments (points)	4.36 (1.12)	4.55 (0.93)	4.64 (0.81)	0.576
	Score reactive postural responses (points)	4.73 (0.79)	4.82 (1.17)	5.10 (1.10)	0.396
	Score sensory orientation (points)	5.36 (1.03)	6.00 (0.00)	5.73 (0.65)	0.091
	Score stability in gait (points)	7.18 (2.04)	8.55 (1.04)	8.27 (1.20)	0.177
TUG	Total duration (sec.)	11.80 (4.50)	12.03 (3.56)	9.98 (4.87)	0.151
	Duration sit to stance (sec.)	1.06 (0.36)	1.05 (0.16)	1.12 (0.27)	0.667
	Duration stance to sit (sec.)	0.83 (0.26)	0.98 (0.23)	0.78 (0.29)	0.102
TUG + double task	Total duration (sec.)	17.18 (7.72)	16.56 (7.57)	16.32 (6.10)	0.695
	Duration sit to stance (sec.)	1.04 (0.22)	1.07 (0.32)	1.13 (0.26)	0.488
	Duration stance to sit (sec.)	1.03 (0.36)	0.75 (0.20)	0.89 (0.30)	0.112
US (Right leg)	Duration (sec.)	14.64 (6.12)	12.79 (7.34)	13.13 (7.98)	0.789
	Acc. mean velocity (m/sec.)	0.33 (0.29)	0.36 (0.29)	0.36 (0.32)	0.695
	Path length (m/sec.)	5.89 (5.43)	27.00 (48.12)	23.59 (43.98)	0.441
US (Left leg)	Duration (sec.)	10.23 (5.79)	11.87 (5.48)	14.83 (6.32)	0.526
	Acc. mean velocity (m/sec.)	0.34 (0.23)	0.37 (0.23)	0.44 (0.27)	0.230

	Path length (m/sec.)	12.89 (10.63)	10.68 (10.94)	8.89 (9.11)	0.913
Timed Chair Stand Test	Total duration (sec.)	19.00 (6.00)	17.14 (4.34)	17.66 (5.62)	0.199
	Duration sit to stance (sec.)	1.11 (0.22)	0.94 (0.31)	1.05 (0.19)	0.178
	Duration stance to sit (sec.)	0.86 (0.12)	0.90 (0.23)	0.90 (0.22)	0.754
10MWT	Cadence (Right leg) (steps/min.)	101.69 (11.97)	102.94 (12.25)	105.33 (7.97)	0.368
	Gait speed (Right leg) (m/sec.)	0.93 (0.28)	0.97 (0.27)	0.99 (0.19)	0.195
	Cadence (Left leg) (steps/min.)	101.92 (11.94)	103.15 (12.38)	105.26 (7.93)	0.434
	Gait speed (Left leg) (m/sec.)	0.94 (0.25)	0.98 (0.27)	1.00 (0.18)	0.304
FES	Total score (points)	26.36 (7.56)	25.18 (11.58)	22.64 (8.10)	0.102

Abbreviations: *SD= standard deviation, acc.= acceleration, m= meter, sec.= seconds, min.= minute P= p-value, TUG= Timed up and go, US= unipedal stance, 10MWT= 10-Meter Walk Test, FES= Falls Efficacy Scale, *= p-value significant <0.05*

5. Discussion

5.1 Key findings

The aim of this study was to investigate the effect of canalith repositioning maneuvers on the postural control in older adults with benign paroxysmal positional vertigo, considering all six underlying mechanisms of balance as stated by Horak et al. Additionally, the effect of these maneuvers on fear of falling in older adults with BPPV was measured. Based on recent literature on the effect of CRM in middle-aged adults with BPPV, it was hypothesised that CRM can improve balance and fear of falling in older adults with BPPV (Blatt et al., 2000; Cohen-Shwartz et al., 2020). This single group pre-post study was only able to detect a significant within-subject effect of the COP path length during stance on a foam with eyes closed (p-value= 0.011). This means that the postural sway while standing on a foam with eyes closed significantly decreased one month after the CRM (p-value= 0.008) and this difference remained three months after treatment (p-value= 0.013). Additionally, there was a nearly significant increase in the number of participants completing the 'eyes closed and foam surface' condition of the CTSIB (p-value= 0.051). These findings indicate that the participants relearned how to solely rely on the vestibular system, because the visual and proprioceptive input are unreliable during this condition. No significant differences over time were found in the other balance mechanisms (biomechanical system, APA's, reactive postural responses, and stability in gait) and fear of falling, indicating that CRM are only effective to improve sensory orientation in older adults with BPPV.

The results of this study are mainly in line with a RCT which detected no significant differences of the dynamic balance in older adults with chronic BPPV, measured with the Dynamic gait index and tandem walk (Ribeiro, Freitas, Ferreira, Deshpande, & Guerra, 2017). The authors also found no significant differences over time for unipedal stance. Like this current study, they only found a significant improvement in the 'eyes closed and foam surface' condition of the mCTSIB after thirteen weeks compared to baseline. These findings should be interpreted with caution due to the moderate methodological quality. Studies investigating the efficiency of CRM on postural balance in middle-aged adults found a significant decrease in: (1) lateral sway during stance three days after the CRM; (2)

anteroposterior sway during stance after 12 weeks; (3) sway velocity during stance on a foam with eyes closed after two weeks; (4) sway velocity during unipedal stance with eyes closed after four weeks and (5) the total duration of the TUG after one week (Chang et al., 2008; Cohen-Shwartz et al., 2020; Giacomini et al., 2002). Additionally, a significant increase in the walking velocity and stride length during the two-minute walk test was found (Cohen-Shwartz et al., 2020). These results, together with the results of this current study, indicate that CRM might be less effective for improving postural balance in older adults compared to middle-aged adults.

As previously stated by other studies, CRM are not always sufficient in patients with BPPV to improve or recover postural balance (Angeli, Hawley, & Gomez, 2003; Blatt et al., 2000; Chang et al., 2006). Despite the negative result on a diagnostic maneuver, some patients complain of residual dizziness, unsteadiness, and anxiety after treatment with CRM (Blatt et al., 2000; Kollen et al.,2006). Additionally, CRM seems to be less effective in older adults with regards to reducing dizziness-related handicap and leads to a higher recurrence rate compared to younger adults (Batuecas-Caletrio et al., 2013; Sim, Tan, & Hill, 2019). This might also be the case when treating BPPV-related postural instability which is supported by this study. A possible explanation why CRM are less effective in older adults is that they might also suffer from presbyvestibulopathy, the deterioration of the vestibular system with age, alongside BPPV. Almost 50% of the older adults aged over 60 years present some form of vestibular physiologic decline, leading to postural instability and gait impairments (Agrawal, Davalos-Bichara, Zuniga, & Carey, 2013; Agrawal et al., 2012; Tuunainen et al., 2011; Xie, Liu, Anson, & Agrawal, 2017). If presbyvestibulopathy is present alongside BPPV, additional vestibular rehabilitation might be beneficial to reduce postural instability after BPPV has resolved. Vestibular rehabilitation (VR) stimulates the recovery of balance by improving the central vestibular compensation that arises from neuroplasticity (Deveze, Bernard-Demanze, Xavier, Lavieille, & Elziere, 2014). This recovery approach is based on three mechanisms: namely habituation, adaptation, and substitution (C. D. Hall & Cox, 2009; Herdman, 2013). A systematic review concluded that VR significantly improves balance control in older adults with a vestibular disorder (Ricci et al., 2010). If presbyvestibulopathy is not present, additional balance training and gait training might be needed to (further) improve postural stability in older adults treated with a CRM.

The total score on the Falls Efficacy Scale did not change significantly over time. A possible explanation for this result is the low average total score of the participants. This was close to the minimum score of the test, leaving little room for a significant decrease. A second possible explanation is that only a significant improvement in sensory orientation and no improvement in the other five balance mechanisms might not be sufficient to induce a significant decrease in fear of falling. However, a correlation analysis between the improvement in fear of falling and the improvement in postural stability should be executed to confirm this hypothesis.

Several factors could explain the non-significant results found in this current study. Firstly, most balance tests were performed with eyes open, allowing the participants to rely on their visual system. As previously mentioned, people with BPPV show an increased postural sway, especially during conditions with a lack of visual or proprioceptive input. Therefore, future studies should include more balance tests with eyes closed. Another reason why this study did not find any significant difference in the other balance mechanisms (biomechanical system, APA's, reactive postural responses, and stability in gait) over time could be that the participants showed no impairments in these balance mechanisms compared to healthy older adults. The mean cadence, main gait speed, mean duration for completing the TUG, and the mean duration during unipedal stance of this study's population is comparable to those of healthy older adults in other studies (Beling & Roller, 2009; Judge, Whipple, & Wolfson, 1994; Leiros-Rodríguez & García-Soidan, 2014; Maughan, Lowry, Franke, & Smiley-Oyen, 2012; Weerdesteyn et al., 2006; Wolfson et al., 1996). This suggests that a significant improvement should not be expected because BPPV did not significantly impair these balance mechanisms in this study. However, future studies should include a control group with healthy older adults to investigate if there is an impairment of the other balance mechanisms in older adults with BPVV. Thirdly, the baseline measurement of each participant was performed one week after BPPV was diagnosed by the physician of the vestibular department of ZOL, which could have led to a decrease in balance impairments before baseline. Additionally, three of the eleven participants showed spontaneous recovery before baseline measurements could be taken and therefore did not receive any canalith repositioning maneuver. For future research, participants with a spontaneously resolved

BPPV should be excluded from the study. BPPV also reoccurred between time point two (one month after baseline) and time point three (three months after baseline) in one participant. This could have influenced the data. Lastly, this study included only a small sample size, namely eleven participants, resulting in a reduced power and a lesser likelihood of rejecting the null hypothesis. Through power analysis, it was estimated that 45 participants are necessary to detect a significant change.

5.2 Reflection on strengths and weaknesses

Several limitations can be pointed out in this single group study. To begin with, there was no control group included in this study. Because of the severity of BPPV, it seemed unethical to assign participants to a sham treatment or no treatment. However, a control group with middle-aged adults diagnosed with BPPV also receiving CRM can be included in a future study protocol to investigate the impact of age. A control group of healthy older adults could also be included to compare their postural balance to that of older adults with BPPV. Another limitation is that the study did not correct for a possible learning effect on the different balance tests. This could be ruled out if the testing at baseline was executed twice, but this was not possible due to practical reasons. This study included a one month and three months follow-up period after baseline for the reassessment of the outcome measures. However, a longer follow-up period (e.g., six months) would better confirm the long-term effects over time. Additionally, the sample size of eleven participants was small, which might have increased the risk of a reduced likelihood to find statistically significant results, a higher risk of a type II error and a higher variance. In conjunction with the single group study design, it might also lead to results that are less generalizable to a wider population. Furthermore, the study group was too small to perform a correlation analysis between for example fear of falling or number of treatment sessions and postural stability. Based on a study on elderly with BPPV, a sample size of 45 participants is necessary in future studies to detect an expected significant difference (Kasse et al., 2010). Lastly, the Friedman test was used for the statistical analysis in case of a non-normal distribution of the data. However, this test is a non-parametric test and thus has a lower power.

Several strengths can also be reported. First, clear inclusion and exclusion criteria were determined, which contributes to a good reproducibility of the study and results in a lower risk of a selection bias. Due to only one drop-out there is a low risk of an attrition bias. Further, this study's average number of treatment sessions with canalith repositioning maneuvers was 1.5, which is in line with a recent meta-analysis (Laurent et al., 2022), indicating that the treatment sessions were correctly executed. Additionally, because the diagnostic maneuvers can induce dizziness and imbalance, balance tests were performed before the diagnostic procedures to rule out their possible influence on the postural balance. Furthermore, multiple tests were used to measure postural balance. By combining these tests, it is possible to differentiate between the different balance mechanisms. Another strength is that two authors independently analysed the data, leading to a lower risk of detection bias. Lastly, no conflict of interest was reported.

5.3 Implications clinical practice and future studies

Further high-quality research with larger sample sizes is needed to confirm the findings of this study. This further research should include a control group with middle-aged adults with BPPV or older adults without BPPV. Participants who had a spontaneous resolution or a recurrence of BPPV should be excluded and additional outcome measures like vertigo, perceived disability or quality of life should also be investigated. Furthermore, participants, assessors and statisticians should be blinded to minimise the risk of a bias. Finally, balance tests with the eyes closed should be used more.

6. Conclusion

This single group pre-post study investigated the effect of canalith repositioning maneuvers on the postural control and fear of falling in older adults with benign paroxysmal positional vertigo. The results indicate that CRM are effective to improve sensory orientation during stance on a foam with eyes closed after one month. This effect remained after three months. CRM might not be effective to improve the other balance mechanisms (constraints on the biomechanical system, anticipatory postural adjustments, reactive postural responses, and stability in gait) and fear of falling in older adults with BPPV. Future randomized controlled trials with larger samples sizes are needed.

7. References

Abou-Elew, M. H., Shabana, M. I., Selim, M. H., El-Refaei, A., Fathi, S., & Fatth-Allah, M. O. (2010). Residual postural instability in benign paroxysmal positional vertigo. Audiological Medicine, 9(1), 8–15. https://doi.org/10.3109/1651386x.2010.537121

Armonk, N. (2019). IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM. Corp. https://www.ibm.com/support/pages/how-cite-ibm-spss-statistics-or-earlier-versions-spss

Agrawal, Y., Davalos-Bichara, M., Zuniga, M. G., & Carey, J. P. (2013). Head impulse test abnormalities and influence on gait speed and falls in older individuals. *Otol Neurotol, 34*(9), 1729-1735. doi:10.1097/MAO.0b013e318295313c

Agrawal, Y., Zuniga, M. G., Davalos-Bichara, M., Schubert, M. C., Walston, J. D., Hughes, J., & Carey, J. P. (2012). Decline in semicircular canal and otolith function with age. *Otol Neurotol, 33*(5), 832-839. doi:10.1097/MAO.0b013e3182545061

Angeli, S. I., Hawley, R., & Gomez, O. (2003). Systematic approach to benign paroxysmal positional vertigo in the elderly. *Otolaryngol Head Neck Surg, 128*(5), 719-725. doi:10.1016/s0194-5998(03)00256-0

Batuecas-Caletrio, A., Trinidad-Ruiz, G., Zschaeck, C., del Pozo de Dios, J. C., de Toro Gil, L., Martin-Sanchez, V., & Martin-Sanz, E. (2013). Benign paroxysmal positional vertigo in the elderly. *Gerontology, 59*(5), 408-412. doi:10.1159/000351204

Beling, J., & Roller, M. (2009). Multifactorial intervention with balance training as a core component among fall-prone older adults. J Geriatr Phys Ther, 32(3), 125-133. doi:10.1519/00139143-200932030-00008

Bhattacharyya, N., Gubbels, S. P., Schwartz, S. R., Edlow, J. A., El-Kashlan, H., Fife, T., . . . Corrigan, M. D. (2017). Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update). *Otolaryngol Head Neck Surg, 156*(3_suppl), S1-s47. doi:10.1177/0194599816689667

Blatt, P. J., Georgakakis, G. A., Herdman, S. J., Clendaniel, R. A., & Tusa, R. J. (2000). The effect of the canalith repositioning maneuver on resolving postural instability in patients with benign paroxysmal positional vertigo. *Am J Otol, 21*(3), 356-363. doi:10.1016/s0196-0709(00)80045-9

Celebisoy, N., Bayam, E., Güleç, F., Köse, T., & Akyürekli, O. (2009). Balance in posterior and

horizontal canal type benign paroxysmal positional vertigo before and after canalith repositioning maneuvers. *Gait Posture, 29*(3), 520-523. doi:10.1016/j.gaitpost.2008.12.002

Chang, W. C., Hsu, L. C., Yang, Y. R., & Wang, R. Y. (2006). Balance ability in patients with benign paroxysmal positional vertigo. *Otolaryngol Head Neck Surg, 135*(4), 534-540. doi:10.1016/j.otohns.2005.10.001

Chang, W. C., Yang, Y. R., Hsu, L. C., Chern, C. M., & Wang, R. Y. (2008). Balance improvement in patients with benign paroxysmal positional vertigo. *Clin Rehabil, 22*(4), 338-347. doi:10.1177/0269215507082741

Cohen-Shwartz, Y., Nechemya, Y., & Kalron, A. (2020). Canalith repositioning procedure improves gait and static balance in people with posterior semicircular canal benign paroxysmal positional vertigo. *J Vestib Res, 30*(5), 335-343. doi:10.3233/ves-200713

Collen, F. M., Wade, D. T., & Bradshaw, C. M. (1990). Mobility after stroke: reliability of measures of impairment and disability. *Int Disabil Stud, 12*(1), 6-9. doi:10.3109/03790799009166594

Csuka, M., & McCarty, D. J. (1985). Simple method for measurement of lower extremity muscle strength. *Am J Med, 78*(1), 77-81. doi:10.1016/0002-9343(85)90465-6

Deveze, A., Bernard-Demanze, L., Xavier, F., Lavieille, J. P., & Elziere, M. (2014). Vestibular compensation and vestibular rehabilitation. Current concepts and new trends. *Neurophysiol Clin, 44*(1), 49-57. doi:10.1016/j.neucli.2013.10.138

Fernández, L., Breinbauer, H. A., & Delano, P. H. (2015). Vertigo and Dizziness in the Elderly. *Front Neurol, 6*, 144. doi:10.3389/fneur.2015.00144

Fife, T. D., Iverson, D. J., Lempert, T., Furman, J. M., Baloh, R. W., Tusa, R. J., . . . Gronseth, G. S. (2008). Practice parameter: therapies for benign paroxysmal positional vertigo (an evidence-based review): report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology, 70*(22), 2067-2074. doi:10.1212/01.wnl.0000313378.77444.ac

Giacomini, P. G., Alessandrini, M., & Magrini, A. (2002). Long-term postural abnormalities in benign paroxysmal positional vertigo. *ORL J Otorhinolaryngol Relat Spec, 64*(4), 237-241. doi:10.1159/000064130

Hall, C. D., & Cox, L. C. (2009). The role of vestibular rehabilitation in the balance disorder

patient. *Otolaryngol Clin North Am, 42*(1), 161-169, xi. doi:10.1016/j.otc.2008.09.006

Hall, S. F., Ruby, R. R., & McClure, J. A. (1979). The mechanics of benign paroxysmal vertigo. *J Otolaryngol, 8*(2), 151-158.

Herdman, S. J. (2013). Vestibular rehabilitation. *Curr Opin Neurol, 26*(1), 96-101. doi:10.1097/WCO.0b013e32835c5ec4

Hilton, M. P., & Pinder, D. K. (2014). The Epley (canalith repositioning) manoeuvre for benign paroxysmal positional vertigo. *Cochrane Database Syst Rev*(12), Cd003162. doi:10.1002/14651858.CD003162.pub3

Horak, F. B., Wrisley, D. M., & Frank, J. (2009). The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Phys Ther, 89*(5), 484-498. doi:10.2522/ptj.20080071

Judge, J. O., Whipple, R. H., & Wolfson, L. I. (1994). Effects of resistive and balance exercises on isokinetic strength in older persons. J Am Geriatr Soc, 42(9), 937-946. doi:10.1111/j.1532-5415.1994.tb06584.x

Kasse, C. A., Santana, G. G., Scharlach, R. C., Gazzola, J. M., Branco, F. C., & Doná, F. (2010). Results from the balance rehabilitation unit in benign paroxysmal positional vertigo. *Braz J Otorhinolaryngol, 76*(5), 623-629.

Laurent, G., Vereeck, L., Verbecque, E., Herssens, N., Casters, L., & Spildooren, J. (2022). Effect of age on treatment outcomes in benign paroxysmal positional vertigo: A systematic review. *J Am Geriatr Soc, 70*(1), 281-293. doi:10.1111/jgs.17485

Leiros-Rodríguez, R., & García-Soidan, J. L. (2014). Balance training in elderly women using public parks. J Women Aging, 26(3), 207-218. doi:10.1080/08952841.2014.888220

Luryi, A. L., Lawrence, J., Bojrab, D. I., LaRouere, M., Babu, S., Zappia, J., . . . Schutt, C. A. (2018). Recurrence in Benign Paroxysmal Positional Vertigo: A Large, Single-Institution Study. *Otol Neurotol, 39*(5), 622-627. doi:10.1097/mao.0000000000001800

Maki, B. E., & McIlroy, W. E. (1997). The role of limb movements in maintaining upright stance: the "change-in-support" strategy. *Phys Ther, 77*(5), 488-507. doi:10.1093/ptj/77.5.488

Marques, A., Almeida, S., Carvalho, J., Cruz, J., Oliveira, A., & Jácome, C. (2016). Reliability, Validity, and Ability to Identify Fall Status of the Balance Evaluation Systems Test, Mini-

Balance Evaluation Systems Test, and Brief-Balance Evaluation Systems Test in Older People Living in the Community. Arch Phys Med Rehabil, 97(12), 2166-2173.e2161. doi:10.1016/j.apmr.2016.07.011

Maughan, K. K., Lowry, K. A., Franke, W. D., & Smiley-Oyen, A. L. (2012). The dose-response relationship of balance training in physically active older adults. J Aging Phys Act, 20(4), 442-455. doi:10.1123/japa.20.4.442

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., . . . Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc, 53*(4), 695-699. doi:10.1111/j.1532-5415.2005.53221.x

Parnes, L. S., Agrawal, S. K., & Atlas, J. (2003). Diagnosis and management of benign paroxysmal positional vertigo (BPPV). *Cmaj, 169*(7), 681-693.

Pereira, A. B., Santos, J. N., & Volpe, F. M. (2010). Effect of Epley's maneuver on the quality of life of paroxismal positional benign vertigo patients. *Braz J Otorhinolaryngol, 76*(6), 704-708.

Reelick, M. F., van Iersel, M. B., Kessels, R. P., & Rikkert, M. G. (2009). The influence of fear of falling on gait and balance in older people. *Age Ageing, 38*(4), 435-440. doi:10.1093/ageing/afp066

Ribeiro, K. M., Freitas, R. V., Ferreira, L. M., Deshpande, N., & Guerra, R. O. (2017). Effects of balance Vestibular Rehabilitation Therapy in elderly with Benign Paroxysmal Positional Vertigo: a randomized controlled trial. *Disabil Rehabil, 39*(12), 1198-1206. doi:10.1080/09638288.2016.1190870

Ricci, N. A., Aratani, M. C., Doná, F., Macedo, C., Caovilla, H. H., & Ganança, F. F. (2010). A systematic review about the effects of the vestibular rehabilitation in middle-age and older adults. *Rev Bras Fisioter, 14*(5), 361-371.

Rodrigues, D. L., Ledesma, A. L. L., de Oliveira, C. A. P., & Bahamad Júnior, F. (2018). Physical Therapy for Posterior and Horizontal Canal Benign Paroxysmal Positional Vertigo: Long-term Effect and Recurrence: A Systematic Review. *Int Arch Otorhinolaryngol, 22*(4), 455-459. doi:10.1055/s-0037-1604345

Rossetti, H. C., Lacritz, L. H., Cullum, C. M., & Weiner, M. F. (2011). Normative data for the Montreal Cognitive Assessment (MoCA) in a population-based sample. *Neurology, 77*(13), 1272-1275. doi:10.1212/WNL.0b013e318230208a

Sachs, B. C., Chelune, G. J., Rapp, S. R., Couto, A. M., Willard, J. J., Williamson, J. D., . . . Pajewski, N. M. (2021). Robust demographically-adjusted normative data for the Montreal Cognitive Assessment (MoCA): Results from the systolic blood pressure intervention trial. *Clin Neuropsychol*, 1-16. doi:10.1080/13854046.2021.1967450

Schlick, C., Schniepp, R., Loidl, V., Wuehr, M., Hesselbarth, K., & Jahn, K. (2016). Falls and fear of falling in vertigo and balance disorders: A controlled cross-sectional study. *J Vestib Res, 25*(5-6), 241-251. doi:10.3233/ves-150564

Shumway-Cook, A., & Horak, F. B. (1986). Assessing the influence of sensory interaction of balance. Suggestion from the field. *Phys Ther, 66*(10), 1548-1550. doi:10.1093/ptj/66.10.1548

Sim, E., Tan, D., & Hill, K. (2019). Poor Treatment Outcomes Following Repositioning Maneuvers in Younger and Older Adults With Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis. *J Am Med Dir Assoc, 20*(2), 224.e221-224.e223. doi:10.1016/j.jamda.2018.11.019

Szturm, T., Reimer, K. M., & Hochman, J. (2015). Home-Based Computer Gaming in Vestibular Rehabilitation of Gaze and Balance Impairment. *Games Health J, 4*(3), 211-220. doi:10.1089/g4h.2014.0093

Tuunainen, E., Poe, D., Jäntti, P., Varpa, K., Rasku, J., Toppila, E., & Pyykkö, I. (2011). Presbyequilibrium in the oldest old, a combination of vestibular, oculomotor and postural deficits. *Aging Clin Exp Res, 23*(5-6), 364-371. doi:10.1007/bf03337761

von Brevern, M., Radtke, A., Lezius, F., Feldmann, M., Ziese, T., Lempert, T., & Neuhauser, H. (2007). Epidemiology of benign paroxysmal positional vertigo: a population based study. *J Neurol Neurosurg Psychiatry, 78*(7), 710-715. doi:10.1136/jnnp.2006.100420

Wolfson, L., Whipple, R., Derby, C., Judge, J., King, M., Amerman, P., . . . Smyers, D. (1996). Balance and strength training in older adults: intervention gains and Tai Chi maintenance. J Am Geriatr Soc, 44(5), 498-506. doi:10.1111/j.1532-5415.1996.tb01433.x

Weerdesteyn, V., Rijken, H., Geurts, A. C., Smits-Engelsman, B. C., Mulder, T., & Duysens, J. (2006). A five-week exercise program can reduce falls and improve obstacle avoidance in the elderly. Gerontology, 52(3), 131-141. doi:10.1159/000091822

Xie, Y. J., Liu, E. Y., Anson, E. R., & Agrawal, Y. (2017). Age-Related Imbalance Is Associated

With Slower Walking Speed: An Analysis From the National Health and Nutrition Examination Survey. *J Geriatr Phys Ther, 40*(4), 183-189. doi:10.1519/jpt.0000000000000093

Yardley, L., Beyer, N., Hauer, K., Kempen, G., Piot-Ziegler, C., & Todd, C. (2005). Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age Ageing, 34*(6), 614-619. doi:10.1093/ageing/afi196

8. Appendix

Appendix 1. *Demographic data*

Participant	Sex	Age (years)	Type of BPPV	N. of treatment sessions needed	MOCA (total score)	Nationality	Living situation
1	M	73	LPSCC	0	22	Italian	With partner
2	M	71	RPSCC	1	26	Belgian	With partner
3	F	73	LLSCC	1	21	Belgian	Alone
4	F	65	RLSCC	1	29	Belgian	With partner
5	F	73	RPSCC	1	19	Belgian	With partner
6	F	76	RPSCC	0	26	Belgian	Alone
7	M	71	RPSCC	4	28	Belgian	With partner
8	M	78	RPSCC	2	22	Belgian	With partner
9	F	76	RPSCC	2	16	Belgian	Alone
10	M	73	LPSCC	3	20	Dutch	With partner
11	F	70	RPSCC	1	21	Belgian	Alone

Participant	Use of walking aid	Weight (kg)	Height (m)	BMI (kg/m^2)	Sleeping pattern	Comorbidities
1	No	66	1.61	25.46	Restless	Cardiovascular, hypertension, rheumatism
2	No	72	1.66	26.13	Restless	Hypercholesterolemia
3	No	75	1.70	25.95	Restless	Vitamin D insufficientie, 2 knee prosthesis, osteopathy
4	No	61	1.63	22.96	No problems	Cardiovascular, cerebrovascular, hypertension, hypercholesterolemia, COPD
5	No	71	1.58	28.44	Restless	Diabetes, hypertension, hypercholesterolemia
6	No	58	1.63	21.83	Trouble falling asleep	Hypotension, osteoporosis, 2 hip prosthesis

Participant	Use of walking aid	Weight (kg)	Height (m)	BMI (kg/m^2)	Sleeping pattern	Comorbidities
7	No	73	1.70	25.26	Restless	Hypertension
8	No	85	1.71	29.07	Restless	Hypertension, chronic back pain
9	Yes	80	1.56	32.87	No problems	Hypertension, hypercholesterolemia, osteoporosis, Kahler's disease
10	No	76	1.68	26.93	No problems	Vitamin D insufficientie
11	No	58	1.62	22.10	No problems	Hypercholesterolemia

Abbreviations: *n.= number, MOCA= Montreal cognitive assessment, m= meter, M= male, F= female, kg= kilogram, RPSCC= right posterior semicircular canal, LPSCC= left posterior semicircular canal, RLSCC= right lateral semicircular canal, LLSCC= left lateral semicircular canal*

Verklaring op Eer

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

1. Ik ben ingeschreven als student aan de UHasselt in de opleiding Revalidatiewetenschappen en kinesitherapie, waarbij ik de kans krijg in het kader van mijn opleiding mee te werken aan onderzoek van de faculteit Revalidatiewetenschappen aan de UHasselt. Dit onderzoek wordt beleid door Prof. Dr. Joke Spildooren 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 geriatrische revalidatie (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;
   - 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;

[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 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. Joke Spildooren.

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: Joke Vanherk

Adres: Kamperbaan 138, 3940 Hechtel

Geboortedatum en –plaats : 07/12/1999 te Lommel

Datum: 10/09/2021

Handtekening: Joke Vanherk

Verklaring op Eer

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

1. Ik ben ingeschreven als student aan de UHasselt in de opleiding Revalidatiewetenschappen en kinesitherapie, waarbij ik de kans krijg om in het kader van mijn opleiding mee te werken aan onderzoek van de faculteit Revalidatiewetenschappen aan de UHasselt. Dit onderzoek wordt beleid door Prof. Dr. Joke Spildooren 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 geriatrische revalidatie (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;
   - 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;

[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 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. Joke Spildooren.

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: Lieselotte Langens

Adres: Apotheker Hendrixstraat 6, 3990 Peer

Geboortedatum en –plaats : 24/07/1999 te Genk

Datum: 10/09/2021

Handtekening: Lieselotte Langens

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
01/12/2022	Bespreking methode	Promotor: Spildooren Copromotor/Begeleider: Student(e): ~~X~~ Student(e): ~~X~~ Vanbeek
16/02/2022	Bespreking aangeleverde data	Promotor: Spildooren Copromotor/Begeleider: Student(e): ~~X~~ Student(e): ~~X~~ Vanbeek
22/03/2022	Bespreking statistiek	Promotor: Spildooren Copromotor/Begeleider: Student(e): ~~X~~ Student(e): ~~X~~ Vanbeek
03/05/2022	Bespreking resultaten	Promotor: Spildooren Copromotor/Begeleider: Student(e): ~~X~~ Student(e): ~~X~~ Vanbeek
12/05/2022	Bespreking resultaten en discussie	Promotor: Spildooren Copromotor/Begeleider: Student(e): ~~X~~ Student(e): ~~X~~ Vanbeek
	<u>Niet-bindend advies</u>: De promotor verleent hierbij het advies om de masterproef WEL/~~NIET~~ te verdedigen. ✓	Promotor: Spildooren Copromotor/Begeleider: Student(e): ~~X~~ Student(e): ~~X~~ Vanbeek

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

Naam Student(e): Joke Vanherk en Lieselotte Langens Datum: 23/05/2022

Titel Masterproef: Can canalith repositioning maneuvers improve the postural balance and fear of falling in older adults with benign paroxysmal positional vertigo?

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

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

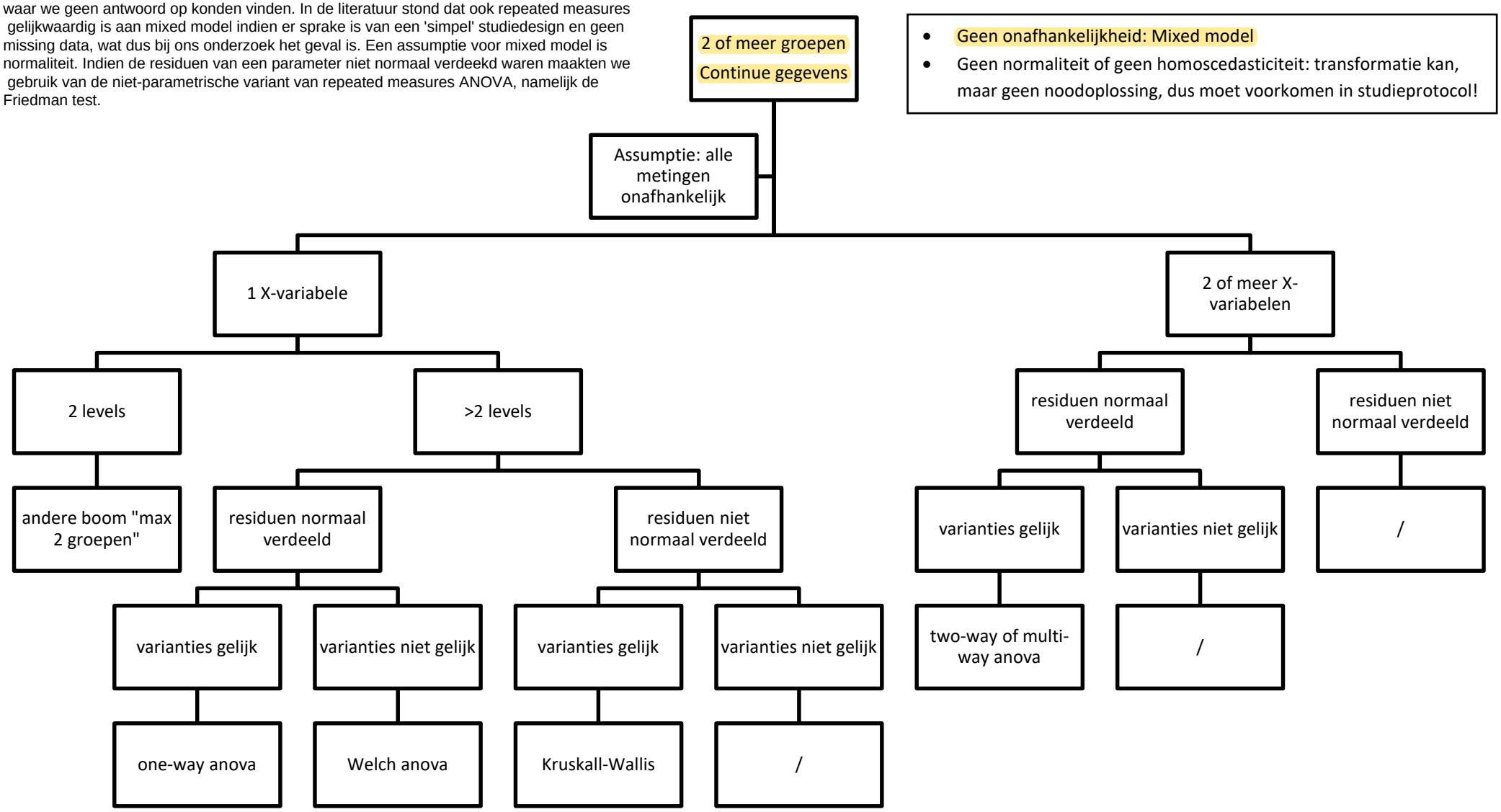
2) Niet-bindend advies: Student(e) krijgt toelating/~~geen toelating~~ (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

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

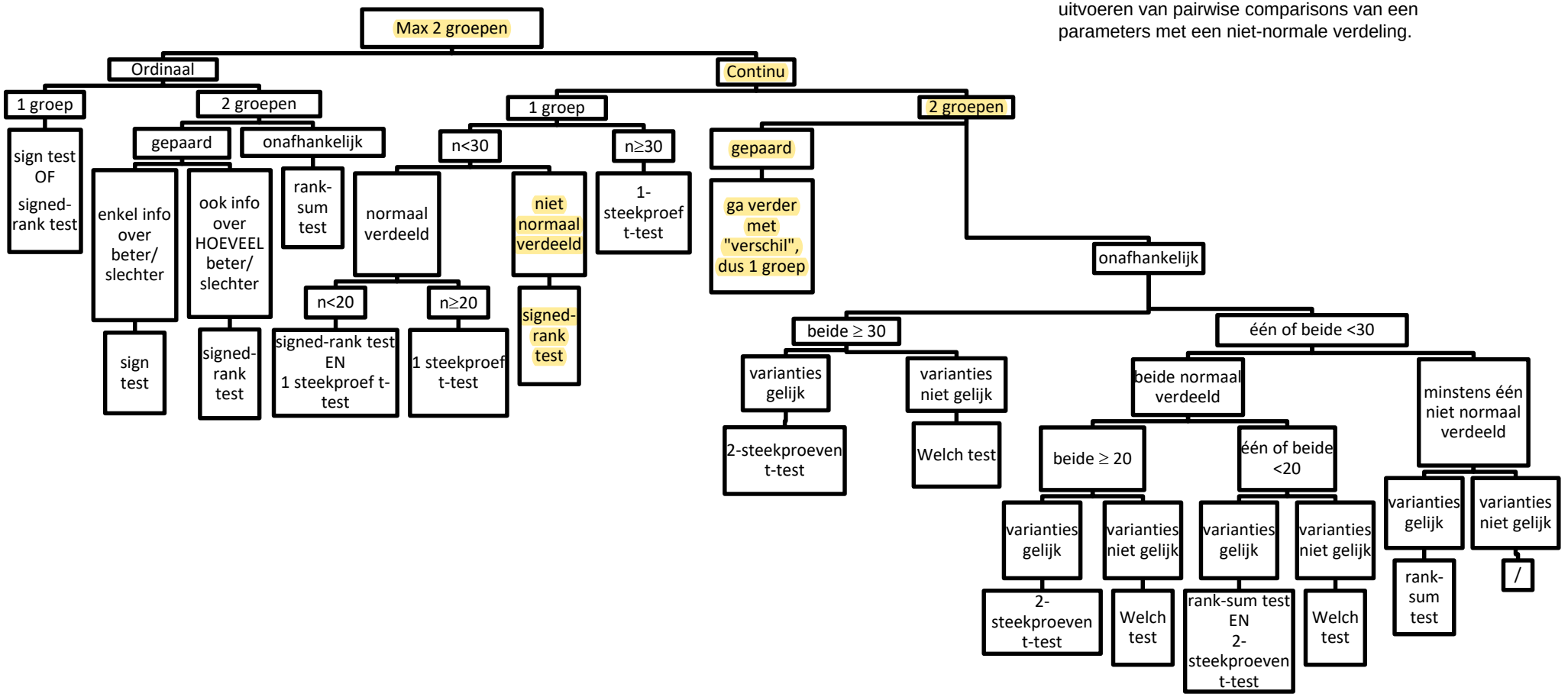
4) Deze wetenschappelijke stage/masterproef deel 2 mag wel/~~niet~~ (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)	Datum en handtekening promotor(en)	Datum en handtekening Co-promotor(en)
Lieselotte Langens Joke Vanherk		

Als we de beslissingsboom volgden dan kwamen we uit bij mixed model omwille van de afhankelijke gegevens. Echter hebben we gebruik gemaakt van repeated measures ANOVA in plaats van mixed model. Repeated measures ANOVA is een variant van mixed model, die beiden gebruikt worden wanneer er sprake is van afhankelijke gegevens. We hebben ervoor gekozen om geen mixed model te gebruiken omwille van de complexe instellingen in SPSS waar we geen antwoord op konden vinden. In de literatuur stond dat ook repeated measures gelijkwaardig is aan mixed model indien er sprake is van een 'simpel' studiedesign en geen missing data, wat dus bij ons onderzoek het geval is. Een assumptie voor mixed model is normaliteit. Indien de residuen van een parameter niet normaal verdeekd waren maakten we gebruik van de niet-parametrische variant van repeated measures ANOVA, namelijk de Friedman test.



Omdat uit de Friedman test bleek dat er een significant verschil was in een parameter tussen de 3 verschillende meetmomenten, werden er pairwise comparisons uitgevoerd om te kijken tussen welke meetmomenten er juist een signifcant verschil was. Als we de beslissingsboom volgdeen kwamen we uit op de Wilcoxon signed-rank test voor het uitvoeren van pairwise comparisons van een parameters met een niet-normale verdeling.



Van: **Joke SPILDOOREN** joke.spildooren@uhasselt.be
Onderwerp: Re: Inschrijvingsformulier en inventarisatieformulier MP2
Datum: 24 mei 2022 om 15:50
Aan: Lieselotte Langens lieselotte.langens@student.uhasselt.be
Kopie: Joke Vanherk joke.vanherk@student.uhasselt.be, Sara PAUWELS sara.pauwels@uhasselt.be

Beste Lieselotte en Joke,

In bijlage nu ook jullie goedkeuring om in te dienen.

Veel succes

Mvg
Joke Spildooren

Prof. Dr. Joke Spildooren
Assistant professor - Geriatric Rehabilitation
REVAL - Rehabilitation Research

T +32(0)11 26 91 78

www.uhasselt.be
Hasselt University - Campus Diepenbeek
Agoralaan Building A - B-3590 Diepenbeek
Office A0.01

Postal address:
Hasselt University
Martelarenlaan 42
B-3500 Hasselt

REVAL
REHABILITATION RESEARCH
UHASSELT

Op ma 23 mei 2022 om 19:53 schreef Lieselotte Langens <lieselotte.langens@student.uhasselt.be>:

> Beste
>
> In de bijlagen vind u het inschrijvingsformulier voor de masterproef verdediging en het inventarisatieformulier. Hierbij vragen we een akkoord om onze masterproef te verdedigen.
>
> Alvast bedankt!
> Met vriendelijke groeten
>
> Joke Vanherk & Lieselotte Langens

PDF Inventarisatieformulier_...erk.pdf

PDF Inschrijvingsformulier_...erk.pdf