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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Impact of Benign Paroxysmal Positional Vertigo (BPPV) and the treatment effect of canal repositioning maneuvers (CRMs) on dizziness, emotional well-being, and the incidence of falling & fall risk in older people

Imme Beesmans
Babette Devue

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 :

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2023

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Setting

This master’s thesis is situated within the research domain of geriatric rehabilitation. The research in which this master's thesis is situated aims to determine the treatment efficacy of Benign Paroxysmal Positional Vertigo (BPPV) and its impact on balance, inactivity, and frailty. This master's thesis will involve a subset of this and, more specifically, it will look at the impact of BPPV and the treatment effect of Canal Repositioning Maneuvers (CRMs) on dizziness, emotional well-being, and the incidence of falling & fall risk in older people.

In older adults, vertigo and dizziness are common problems; BPPV has a very large share in this. Having BPPV affects their daily lives in many ways. It is essential to know what aspects BPPV affects and if and how these problems can be fixed.

This master's thesis was written for the subject: physical therapy and rehabilitation. The topic of this thesis is situated within ongoing research for dra. Sara Pauwels' research project. The research was conducted at the vestibular department of Hospital Oost-Limburg (ZOL) Genk.

The research was conducted by dra. Sara Pauwels, who sometimes received help from students from the first master's program in 'Rehabilitation Sciences and Physiotherapy' at UHasselt. The data were processed and delivered to us for writing the master's thesis.

This master's thesis is the work of two students. Both students had a share in part of the data collection. There was a good cooperation while writing the master's thesis. Both students worked on all parts of the thesis. While Imme Beesmans focused more on writing the text and supporting it with evidence, Babette Devue focused more on performing the statistics and creating the accompanying figures; she also checked the text and ensured correct English was used everywhere. Mutual consensus eventually led to a final version.

Abstract

Background and Purpose

Benign paroxysmal positional vertigo (BPPV) is the most common vestibular disorder. It is treated effectively with Canal Repositioning Maneuvers (CRMs). This study aimed to assess the impact of BPPV and the treatment effect of CRMs on dizziness, emotional well-being, and the incidence of falling & fall risk in older people.

Methods

Forty-three people completed the study. After the presence of BPPV was assessed, the 43 people were divided into two groups: BPPV and control group. They completed Dizziness Handicap Inventory (DHI), Falls Efficacy Scale (FES), Geriatric Depression Scale (GDS-15), Timed Up and Go (TUG), and Timed chair stand test (TCST). Participants within the BPPV group were treated with CRMs. All assessments were retaken one month after the first assessment.

Results

A significant difference between the BPPV and the control group was found based on the results of the DHI and its subscales, the FES-I, the TUG, and fall risk. Treatment with CRPs was found to be effective within one month in fourteen out of the 24 BPPV patients and consequently had a significant effect on the results of the DHI and fall risk.

Conclusion

Having BPPV increases dizziness during daily activities, fear of falling, fall risk, and the TUG performance time. It does not affect fall incidence, TCST time, and depressed feelings. Treatment with CRPs significantly decreases dizziness during daily activities and fall risk but does not affect TUG time and fear of falling.

Key words

Benign Paroxysmal Positional Vertigo; BPPV; Balance; Depression; Fall incidence; Fall risk; Falls

Introduction

Benign paroxysmal positional vertigo (BPPV) is the most common vestibular disorder (Zhang et al., 2021a). In older persons over 80 years of age, the prevalence of dizziness and vertigo can rise to 50%. In ⅓ of these cases, BPPV is the cause of the complaints. BPPV is more prevalent in the age group above 60 years of age (Neuhauser, 2016; Jönsson et al., 2004). BPPV incidence is significantly higher in women than men, with a lifetime prevalence of respectively 3.2% and 1.6% (Von Brevern et al., 2006).

BPPV is a benign disorder of the vestibular system located in the inner ear. The typical presentation of BPPV consists of recurrent attacks of positional vertigo or positional dizziness provoked by lying down, turning over in a supine position, or other head movements; these attacks typically last less than one minute (Imai et al., 2017; von Brevern et al., 2015; You et al., 2018). It demonstrates a specific paroxysmal positional nystagmus (Bhattacharyya et al., 2017) caused by the moving of calcium crystals, typically found in the utricular macula. When changing head position, the crystals have come loose or have already degenerated and start moving in the inner ear fluid of the semicircular canals, usually the posterior canal, more rarely the horizontal or anterior ones (Cherniack et al., 2008; Epley, 1995; Hall et al., 1979). There are some pathophysiological concepts of BPPV: cupulolithiasis and canalolithiasis. Schuknecht (1969) proposed the theory of cupulolithiasis: otolithic debris attaches to the cupula, making the cupula heavy and subject to gravity. This allows the cupula to be deflected by positional changes, which can lead to nystagmus. According to Hall et al. (1979), in canalolithiasis, otolithic matter from the utricular macule migrates into the semicircular canal through the non-ampullary section, creating endolymph during positional changes and causing vertigo and nystagmus.

Diagnostic tests, such as the Dix Hallpike maneuver (Dix & Hallpike, 1952) for the posterior canal or the Supine Roll (Bhattacharyya et al., 2008; Fife et al., 2008) for the horizontal canal, can provoke a typical nystagmus. BPPV can be treated using specific therapeutic maneuvers such as Epley (Epley, 1992) or Semont (Semont et al., 1988) for the posterior canal and Barbecue roll (Asprella Libonati, 2005) or (modified) Gufoni (Gufoni et al., 1998) for the horizontal canal. After

treatment, there is improvement in vertigo in all age groups, but adults over 65 have poorer recovery of dynamic balance and an increased perception of disability (Sim et al., 2019). BPPV is often self-limiting and can significantly impact the quality of life (Barnard & Colón-Emeric, 2010; Dix & Hallpike, 1952).

Dizziness affects three aspects of quality of life: emotional, functional, and physical (Zhu et al., 2020). The more severe the dizziness complaints, the higher the people score on questionnaires about anxiety and depression (Zhu et al., 2020). Conversely, individuals with depressive disorders have a higher risk of developing BPPV, especially if they suffer from hyperthyroidism (Hsu et al., 2019). Individuals with undiagnosed BPPV are also more likely to experience depressive episodes (Oghalai et al., 2000; Hawke et al., 2021).

According to Pauwels et al. (2023), the number of fallers is significantly higher for patients with BPPV than for controls. After treatment with CRMs, gait velocity during level walking increased significantly. According to different gait assessment scales, gait became safer. The number of falls, the number of patients with BPPV who fell, and the fear of falling decreased (Pauwels et al., 2023). Hawke et al. (2021) indicates that undiagnosed BPPV is common in rehabilitation outpatients with a high fall risk.

This study aims to determine the impact of BPPV and the treatment effect of (CRMs) on dizziness, emotional well-being, and the incidence of falling & fall risk in older people. Our hypothesis states that participants with BPPV will have an increased fall risk, fall incidence, fear of falling, and experience of dizziness compared to the control group before treatment. Because of this, we expect patients to report more feelings of depression. After successful treatment, we expect a decrease in fall risk and incidence; thus, the fear of falling might also disappear. They might experience less dizziness, and because of the decrease in these symptoms, feelings of depression might also decrease. One month after treatment, we expect improvement in patients' symptoms but also expect them to remain poorer compared to a healthy, age-related control group.

Methods

The study design was a non-equivalent pretest-posttest control group design.

Participants

The study has two groups: a BPPV group and a control group. The participants in the BPPV group were older adults living at home (≥ 65 years) who were diagnosed with BPPV in the vestibular department of the Oost-Limburg Hospital (ZOL) in Genk. If there was a suspicion of BPPV or if patients met the inclusion criteria, they were referred to dra. Sara Pauwels by the doctors or audiologists.

The control group included older adults who matched the subjects in the BPPV group based on age, gender, and height. These persons were contacted through the network of the researchers, ‘Seniorenuniversiteit Vlaanderen,’ 'OKRA Limburg,’ and 'Happy Aging Bioville.’ Partners of the participants in the BPPV group were also asked if they wanted to participate in the study.

Inclusion criteria of the BPPV group were: 1) persons ≥ 65 years old, 2) able to stand independently for at least 30 seconds, 3) able to walk with or without a walking aid for at least 10 meters, 4) patients diagnosed with posterior semicircular canal BPPV, 5) patients diagnosed with horizontal canal BPPV.

The inclusion criteria of the control group were: 1) persons ≥ 65 years old, 2) able to stand independently for at least 30 seconds, and 3) able to walk with or without a walking aid for at least 10 meters.

Exclusion criteria were: 1) unable to understand and follow simple instructions (e.g., due to severe dementia, hearing loss, or visual impairment), 2) persons temporarily or permanently living in a residential or psychiatric care center, a home for the disabled or rehabilitation center, 3) persons with contra-indications for the diagnostic maneuver (e.g., severe limitation in the mobility of the cervical spine), 4) persons with evolutionary disorders of the central nervous system (e.g., multiple sclerosis, Parkinson’s disease, amyotrophic lateral sclerosis), 6) persons

still in the rehabilitation phase after an orthopedic or cardiovascular incident. 7) spontaneous resolution of BPPV before completing the entire pre-test data collection.

Procedure

Informed consent was handed out and explained to all participants before entering the study.

Different questionnaires and tests were performed at different measurement times. During the intake (T0) in the Hospital of Oost-Limburg (ZOL), general characteristics were asked, such as gender, date of birth, nationality, living situation (living together or alone), weight (kg), height (m), walking aid (no walking aid/walking stick/4-wheel walker), sleeping pattern (good sleeper/hard time falling asleep/restless sleeper), comorbidities (the number of comorbidities and what these comorbidities are), whether they took supplements or vitamins. Cognitive capabilities were assessed with the Montreal Cognitive Assessment (MoCa).

The presence or absence of BPPV was assessed at T0, and the symptoms of BPPV were also surveyed. They were asked whether they experienced a spinning sensation or felt dizzy when performing head movements. If they experienced dizziness, additional questions were asked, such as which movements provoked it and how long the feeling lasted. The fall history was also determined during the intake by asking the subjects how many times they had fallen over the past year. After this, the test subjects were called every two weeks and asked whether they had fallen in the past two weeks; this was further noted as the number of falls. If they had fallen, they were also asked how often, when, and in what situation. Dizziness, emotional well-being, and fall efficacy questionnaires were completed at home after the intake.

Maximum 7 days after they were handed the questionnaires (T1), the participants had to return to ZOL to check and discuss the filled-in questionnaires. Balance is examined at ZOL at T1. Participants in the BPPV group were, if BPPV was still present, treated with the appropriate CRM. After one CRM, it was rechecked whether BPPV was still present. If BPPV was still present, a second CRM was executed. After the CRMs, an appointment was made to return to the hospital a week later, when it was rechecked whether BPPV was still present. Previous treatment

was repeated when BPPV was still present. If participants with BPPV at T0 did not have BPPV at T1 anymore, they were excluded due to an incomplete dataset.

One month after T1 (T2), all tests were administered again by dra. Sara Pauwels, or by master students of 'Rehabilitation Sciences and Physiotherapy' from the University of Hasselt, under the supervision of dra. Sara Pauwels. Tests at T2 were also performed at ZOL.

If BPPV is diagnosed at T0 and T1, treatment was also performed. The Epley maneuver (Epley, 1992) for treating the posterior canal BPPV consists of five positions. (A) The patient sits upright, and the therapist turns the head 45° to the affected side. (B) The patient is quickly placed on their back with the head hanging off the table. This position is held for 20-30 seconds. (C) Then the head is turned to the unaffected side and held for 20 seconds. (D) The head is turned even further, so the nose almost points down. For this, the patient must shift from supine to side lying. This position is also held for 20-30 seconds. (E) Finally, the therapist returns the patient to a sitting position. A contraindication to performing the Epley maneuver is when the patient suffers from cervical spine disease; then, the Semont maneuver is used (Semont et al., 1988)

The Gufoni maneuver was used to treat the horizontal canal (Gufoni et al., 1998). The patient sits upright on a treatment table. They are quickly placed on one side: the unaffected side for geotropic and the affected side for ageotropic BPPV. This position is held for two minutes. The therapist then turns the patient's head 45° downwards for group BPPV and 45° upwards for group BPPV. This position is also held for two minutes. Finally, the patient is returned to an upright sitting position, which is held for two minutes. *We use this maneuver when performing the barbecue roll* (Asprella Libonati, 2005) *is impossible due to obese persons, cervical spondylosis, musculoskeletal disorders, or age.* (Appiani et al., 2001; Oron et al., 2015)

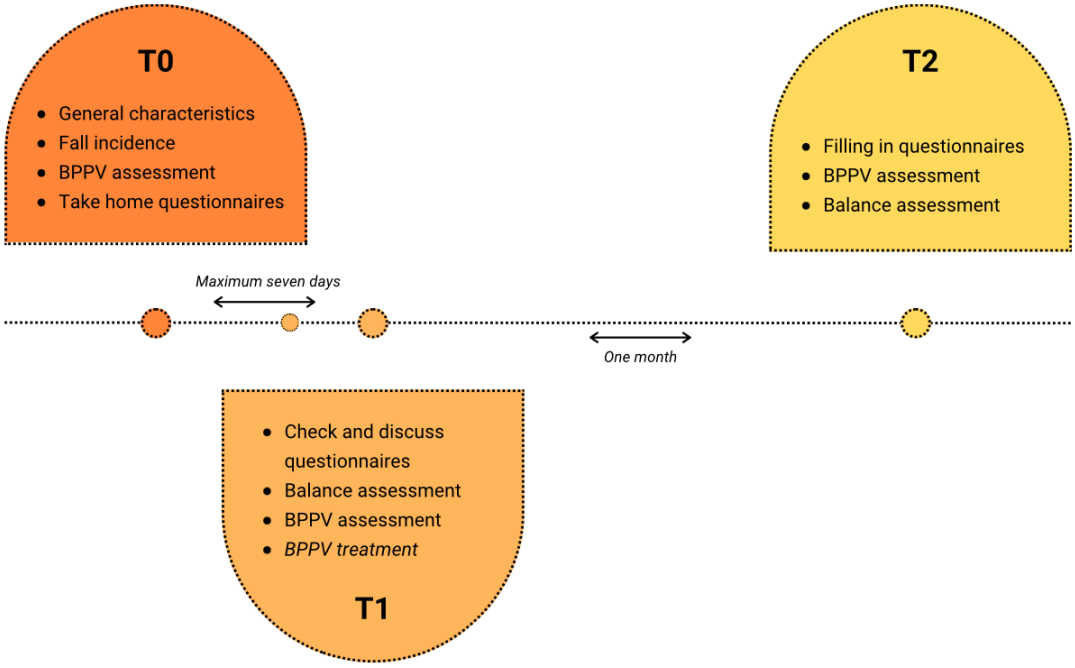


Figure 1

Procedure timeline

Outcome measures

Dizziness Handicap Inventory

To assess the experience of dizziness among the participants, the Dizziness Handicap Inventory (DHI) was used (Jacobson & Newman, 1990). The DHI is the most widely used self-reported measure of dizziness while performing daily activities among patients (Mutlu & Serbetcioglu, 2013). It is a reliable, well-validated, and clinically useful tool for measuring self-perceived disability associated with vertigo symptoms (Treleaven, 2006). The items are grouped into three domains: emotional (nine items), functional (nine items), and physical (seven items). Each item has three possible answers (often, sometimes, and never), and each answer is rated four, two, and zero points, respectively. Total questionnaire scores range from zero to 100, where zero indicates no perceived disability and 100 indicates maximum perceived severity due to dizziness (Jacobson & Newman, 1990).

Falls Efficacy Scale - International

The Falls Efficacy Scale (FES-I) was used to measure the fear of falling while performing daily activities (Tinetti et al., 1990; Yardley et al., 2005). This questionnaire consists of sixteen questions that consist of several functional activities. These are scored based on their concerns about falling while doing this activity. Participants are asked to score each activity, even when not performing it. The scores are summed to calculate a total score range from a minimum of sixteen to a maximum of 64. A higher score indicates a greater fear of falling (Dewan & MacDermid, 2014; Tinetti et al., 1994).

Geriatric Depression Scale

The Geriatric Depression Scale (GDS-15) questions feelings of depression in older adults (Sheikh & Yesavage, 1986; Almeida & Almeida, 1999a; Almeida & Almeida, 1999d). The questionnaire consists of fifteen questions that older adults answer with yes or no. Depending on the questions, based on the scoring key, the answers are scored as zero or one. A total score of zero to four corresponds to not feeling depressed, five to ten to feeling mildly depressed, and eleven or more to feeling depressed (Shin et al., 2019).

Timed Up and Go

Timed Up and Go was used to screen balance deficits that increase fall risk in older adults (Podsiadlo & Richardson, 1991; Nightingale et al., 2019). This test measures the time the person takes to stand up, walk three meters comfortably straight ahead, turn around, walk back, and finally sit back down immediately (Podsiadlo & Richardson, 1991). The TUG was initially used to predict the risk of falling. A time of >13.3 seconds is often used as a cut-off to identify individuals with a high risk of falling (Lindell et al., 2021a).

Timed Chair Stand Test

The Timed Chair Stand Test was used to determine lower limb strength (Guralnik et al., 1994; Bohannon, 1995). The patient must stand up and sit back down as quickly as possible five times

without using their arms. The faster the subjects can stand up and sit down five times, the better their performance (Guralnik et al., 1994)).

Data analysis

IBM SPSS Statistics was used to analyze the normality of all data and the two groups' base characteristics. Significance was set at $\alpha<0.05$ for all analyses. Normality was checked by performing a Shapiro-Wilk test. The Shapiro-Wilk test confirmed that all baseline characteristics data met the assumptions of population normality; because of that, the data could be analyzed parametrically. Homogeneity of variance was verified with Levene's Equality of Error Variances test, which looked at p-values based on means. On this basis, equal variances were assumed for the parameters of gender and weight; the variances were not considered equal for height.

As normality and equal variances were confirmed, the age and weight base characteristics data were conducted with independent-sample T-tests combined with Mann-Whitney U tests (as one of the samples was smaller than twenty). A Welch test was performed as equal variances could not be assumed for the height parameter. A chi-square test was conducted to collect the data on the characteristic gender and the parameter of sleeping patterns. A Mann-Whitney U test was also used to collect the data for comorbidities. Two-sided tests were looked at for all the basic characteristics to see if there was a difference between the two groups.

SAS JMP was used for all other statistical analyses. A mixed model was conducted for each test variable; DHI, FES-I, GDS-15, TUG, and TCST. One-sided tests were looked at with the hypothesis that the BPPV group would achieve higher scores on DHI, FES-I, and GDS-15 and would take longer to perform the TUG and TCST. After performing the mixed model, Tukey-HSD was used as a post hoc test when significant interaction effects were found. A contingency analysis, with Fisher's Exact test, was performed to see if there were any differences in the number of people with increased fall risk. A Bonferroni correction was applied for multiple testing with DHI and DHI subscales.

Decision trees for statistical analyses can be found in **Appendix 1**.

Results

Patient characteristics

Initially, 34 subjects with BPPV and twenty controls participated in the study. After T0, three people with BPPV dropped out, two because of fear of Covid, and one because they no longer wanted to be made dizzy, so they were excluded. At T1, six subjects had a spontaneous resolution; these patients were also excluded. After T1, again, one person dropped out after T1 without giving a specific reason. One control subject dropped out of the study because of fear of COVID-19. The other nineteen control subjects completed the whole investigation.

The final sample included 43 people: 24 subjects with BPPV and nineteen controls (Fig. 2). Based on a sample size calculation that was performed, a sample of approximately 180 participants is needed to draw conclusions for the entire population of older adults with BPPV in Flanders. This study did not meet this requirement.

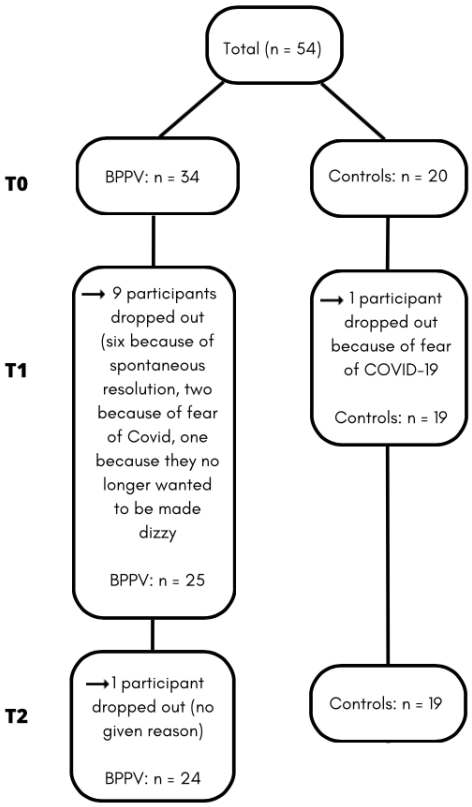


Figure 2
Population flow chart

The BPPV and control group participants could be matched based on age, gender, height, and weight. Also, no significant difference could be found in the number of comorbidities. A significant difference was, however, found between the BPPV and control groups when looking at sleeping patterns (P = 0.023). Participants indicated how they slept in 3 ways. Good sleepers, restless sleepers, and individuals who had difficulty falling asleep. The largest proportion of the BPPV group indicated they were good sleepers (n = 15), while the remaining participants indicated they were restless (n = 9). In the control group, a smaller proportion indicated that they were good sleepers (n = 11), some of them had difficulties falling asleep (n = 4), and the remaining participants were restless sleepers (n = 4). When looking at the two groups' fall history and number of falls, no significant difference was found in fall history, or number of falls

The base characteristics of all participants can be found in **Table 1**.

Table 1. Participant demographic data

Demographic	BPPV group	Control group	p-value
Age (mean, range, ± SD, years)	72.88, 18, ± 4.619	73.53, 16, ± 4.937	.66/.91**
Sex ratio n(male/female)	24 (12/12)	19 (10/9)	.83
Height (mean, ± SD, cm)	165.63, ± 8.826	169.26, ± 5.886	.11
Weight (mean, range, ± SD, kg)	77.19, 44.00, ± 11.295	73.03, 28.00, ± 8.600	.13/.19**
BPPV assessment one month after treatment (T2) (Positive/Negative)	10/14	0/19	/
Fall history (no falls/at least one fall)	17/7	16/3	.47
Number of falls (no fall/one fall/two falls)	17/5/2	16/3/0	.26
Walking aid (none/walking stick or crutch/4 wheel walker)	21/2/1	19/0/0	.16
Comorbidities (mean, ± SD)	2.38, ± 1.527	2.11, ± 1.329	.72
Living situation (alone/with a partner)	6/18	6/13	.74
Sleeping pattern (sleeps well without problems/takes a long time to fall asleep/restless sleeper)	15/0/9	11/4/4	.02*

SD: *Standard Deviation,* n: *number of subjects sampled,* BPPV: *Benign Paroxysmal Positional Vertigo*

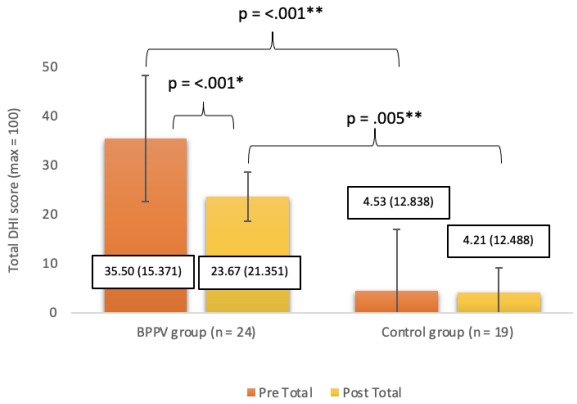
* Statistically significant difference between the BPPV and the control group ($p < .05$)

** p-value independent samples t-test/p-value Mann-Whitney U test

Dizziness Handicap Inventory

A significant difference was found between the BPPV and the control group (P = <.001) when looking at the main effects based on DHI scores. Participants in the BPPV group reported a significantly higher DHI score, which means they experienced more dizziness. A significant difference was also found in measurement time (P = .005). A significant interaction effect was seen in group and measurement time (P = .007).

Fig. 3 shows the results based on the DHI scores. After performing posthoc tests and looking further into the interaction effect, we found that patients with BPPV reported a significantly higher DHI score than participants in the control group before (P = <.001) and after treatment (P = .005). This means patients with BPPV were significantly more dizzy while performing daily activities compared to a healthy, age-related control group before and after treatment. However, a significant treatment effect was found as we see a significant decrease in DHI score within the BPPV group over time (P = <.001).



BPPV: *Benign Paroxysmal Position Vertigo,* SD: *Standard Deviation,* Pre: *Before treatment,* Post: *After treatment*

** Statistically significant difference between BPPV and Control group (p < .0125 after Bonferroni correction)*
*** Statistically significant difference within BPPV or Control group pre vs. post treatment (p < .0125 after Bonferroni correction)*

Figure 3

Dizziness Handicap Inventory (DHI) mean (SD) scores

One month after treatment, ten out of 24 BPPV patients still tested positive for BPPV. This may have possibly caused the mean DHI score to remain still too high to no longer have a significant difference with the control group one month after treatment.

Mean (SD) scores of the subscales of the DHI can be seen in **Table 2**. We saw a significant difference between the groups in all subscales, emotional (P = <.001), functional (P = .002), and physical (P = <.001). Within the emotional subscale, this was the only significant difference we saw; with the physical subscale, there was also a significant measurement time effect (P = .001). We saw a significant interaction effect between group and measurement time for the functional (P = .008) and physical (P = .001) subscales. Looking further into the interaction effect, the

functional subscale showed a significant difference between the BPPV and the control group before treatment (P = <.001); after treatment, this significant difference was no longer present (P = .33). After performing a Bonferroni correction for multiple testing, there was also no significant difference seen in the scores within the BPPV group before and after treatment (P = .05). Looking further at the physical subscale, we saw a significant difference between the BPPV and control groups both before (P = < .001) and after (P = < .001) treatment. However, we also saw a significant difference within the BPPV group between before and after treatment (P = <.001), allowing us to speak of a significant treatment effect.

Table 2. Dizziness Handicap Inventory (DHI) subscale and total scores

Subscale scores	**BPPV group**		**Control group**		**p-values**		
	Pre	Post	Pre	Post			
	mean (SD)	*mean (SD)*	*mean (SD)*	*mean (SD)*	Group effect	Time effect	Interaction effect
Emotional (max. = 36)	7.25 (5.135)	5.25 (6.401)	1.16 (4.180)	0.95 (3.291)	<.001*	.14	.20
Functional (max. = 36)	13.42 (7.378)	8.92 (9.193)	1.68 (5.260)	4.21 (12.488)	.002*	.44	.008**
Physical (max. = 28)	14.83 (4.641)	9.50 (6.679)	1.58 (4.141)	1.58 (4.032)	<.001*	.001*	.001**

SD: *Standard Deviation,* BPPV: *Benign Paroxysmal Positional Vertigo,* max: *maximum,* pre: *before treatment (T1),* post: *after treatment (T2)*

* Statistically significant difference in main effect between groups or within measurement time (p < .0125 after Bonferroni correction)
** Statistically significant difference in interaction effect of groups with measurement time (p < .0125 after Bonferroni correction)

Timed Up and Go

When looking at the TUG time and its main effects, a significant difference could be found between the BPPV and the control group (P = .02). Participants with BPPV need a significantly longer time to perform the TUG. No significant difference could be found when looking at measurement time (P = .16). Also, no interaction effect was found in groups and measurement time (P = .29).

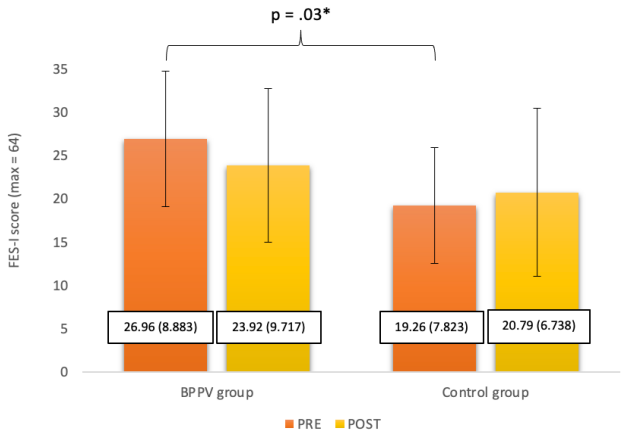
Timed Chair Stand Test

No significant differences could be found when looking at the TCST time, nor between groups (P = .20), nor when looking at measurement time (P = .76). Also, no interaction effect of groups with measurement time was found (P = .73).

Falls Efficacy Scale - International

When looking at the main effects based on FES-I scores, a significant difference could be found between the BPPV and the control group (P = .03). Thus, participants in the BPPV group report a significantly higher fear of falling. No significant difference could be found when looking at measurement time (P = .35). However, a significant interaction effect of group and measurement time was found (P = .04).

When looking further into the interaction effect, comparing the FES-I-scores between the BPPV and the control group before treatment, we see significantly higher scores in the BPPV group (P = .03). This means having BPPV causes a significantly higher fear of falling. When looking at the differences within the BPPV group before and after treatment, we see no significant improvement in FES-I-scores (P = .13). Treating BPPV, thus, does not influence the fear of falling significantly within one month after treatment. However, one month after treatment, no statistically significant difference could be seen anymore comparing the FES-I-scores between the BPPV and the control group (P = .83). The mean score on the FES-I decreased in the BPPV group after treatment. Still, at this same time, the mean score increased in the control group. This may explain why there was no longer a significant difference between the two groups after treatment, but also no significant treatment effect. FES-I data can be found in **Fig. 4.**



BPPV: *Benign Paroxysmal Position Vertigo,* SD: *Standard Deviation,*
Pre: *Before treatment,* Post: *After treatment*

** Statistically significant difference between BPPV and Control group (p < .05)*

Figure 4

Falls Efficacy Scale - International (FES-I) mean (SD) scores

Fall Risk & Incidence

No significant difference between the two groups could be found in the fall history (before treatment (P = .47). The same applies to the number of falls after treatment (P = .26).

When looking at fall risk before treatment, we saw a difference between the BPPV and the control groups. Significantly more patients with BPPV showed an increased fall risk compared to the control group (P = .014). After treatment, no significant difference between the two groups was found (P = .45). People with BPPV, thus, might have a higher risk of falling, for which dizziness may be a cause. Treatment showed to decrease the number of people with an increased fall risk.

Geriatric Depression Scale - 15

GDS-15 scores did not appear significantly different when comparing the BPPV and the control group (P = .19). Thus, having BPPV does not cause a significantly higher score for depression. The same applies when looking at the main effect measurement time; again, there was no significant difference (P = .43). Also, no interaction effect of groups with measurement time was found (P = .36).

Discussion

This study investigated the effect of BPPV and the treatment effect of CRMs on dizziness when performing daily activities, emotional well-being, fall incidence, and fall risk. Based on the results of this study, BPPV had an impact on dizziness, fear of falling, and performance of the TUG. No significant difference could be found in emotional well-being and number of falls. Patients with BPPV might have a higher risk of falling, as they had a significantly higher TUG time when compared with the control group. The fact that ten of the 24 BPPV patients still tested positive for BPPV one month after treatment may have influenced the results and their significance. A longer follow-up period with more treatments could have a better effect on this.

BPPV patients do not have significantly poorer sleep quality than a healthy, age-related control group, as found in this study. However, according to Iranfar and Azad (2022), having sleep disorders and using sleep medication are significantly more frequent in BPPV patients compared to a control group. Wang et al. (2018) found that BPPV patients with poorer sleep quality seem to have a higher risk of recurrence of BPPV.

According to the results of this study, BPPV patients reported significantly more dizziness while performing daily activities compared to a healthy, age-related control group, both before and after treatment with CRMs. However, a significant treatment effect could be found as BPPV patients reported a statistically significant decrease in dizziness while performing daily activities. Da Silva et al. (2015) found similar results and reported significant improvement in DHI scores and subscale scores after treatment with CRMs. However, Ke et al. (2022) found that longer follow-up periods are needed as most BPPV patients still had BPPV when re-evaluating at one week and one-month post-treatment. Despite receiving effective treatment with CRMs, residual dizziness (RD) develops in more than half of the BPPV patients (Ke et al., 2022). However, according to Da Silva et al. (2015), RD may occur after a longer period than one month after treatment, so these results were not found in this study. In this study, a longer follow-up period, during which treatment was effective in more patients, could ensure that the degree of dizziness in performing daily activities after treatment was no longer significantly higher in a BPPV group compared with a control group.

This study found a significant difference in the patients with BPPV and the control group on the TUG. However, we did not see a significant difference in comparing the TCST results between the groups. Thus, the significant difference in the TUG could be due to a lower walking speed and turn characteristics, as these aspects are not assessed with the TCST. Zhang et al. (2021b) found that people with BPPV had a shorter stride length and slower cadence, which could lead to slower walking speed. According to Cohen-Shwartz et al. (2020), there was no significant difference in turn characteristics between people with BPPV and the control group. After CRMs, improvements were found in the duration of the TUG. People with BPPV walked faster after treatment with CRMs, including the turn. (Cohen-Shwartz et al., 2020). However, no significant treatment effect could be found in this study when looking at the TUG, possibly because

treatment was ineffective in 10 out of 24 BPPV patients. This may have caused the mean TUG test time to remain too high one month after treatment to speak of a significant treatment effect. Pauwels et al. (2023) found that gait velocity did not improve until six to twelve months after treatment and that patients with BPPV one month after treatment may still rely more on other sensory systems, such as vision, causing them to walk more slowly. This can also explain the fact that no significant treatment effect was found when looking at TUG test time in this study. According to Vaz et al. (2013), the time of people with BPPV on the TUG did improve significantly after CRPs due to improved dynamic balance. Rodrigues et al. (2019) found that adding vestibular exercises to performing CRPs improved symptoms such as vertigo and showed a strong association in reducing recurrence. In the study by Rodrigues et al. (2019), the protocol of Cawthorne and Cooksey was used. Eye and head movements were done in a sitting position in the first session, with the build-up being trained on dynamic exercises and balance until the fifth session. The addition of vestibular rehabilitation in this study would possibly also have been beneficial in improving balance and possibly in the effectiveness of treatment.

Because no significant difference was seen in the TCST between people with BPPV and the control group in our study, we can state that muscle strength is not affected in older adults with BPPV compared with a healthy, age-related control group. This is consistent with the findings of Lin et al. (2020); in this study, it was found that people with BPPV had similar lower extremity muscle strength compared to other older adults.

This study found that the number of patients with increased fall risk was significantly higher in BPPV patients compared to a control group before treatment. This is consistent with the findings of Pauwels et al. (2023), who found that people with BPPV are likelier to fall than those without BPPV. Thus, the treatment proved sufficiently effective to make the significant difference in the number of individuals with increased fall risk insignificant, but not sufficiently effective to do the same for the difference in TUG test time. Correct and timely diagnosis of BPPV can reduce the risk of falling (Laurent et al., 2022). Further research must be done to learn more about BPPV and fall risk.

Lindell et al. (2021b) indicates that persons with BPPV actually fall more. That is not consistent with the findings of this study, as no significant difference was found when comparing both groups based on fall history (before treatment) and number of falls (after treatment). In this study, fall history was questioned based on a yes/no question of whether or not they had fallen in the past year. Thus, there is no data on how often the participants had fallen, which might have made the difference between the groups significant. After performing CRPs, Ganança et al. (2010) and Jumani & Powell (2017) observed that the number of falls was significantly reduced. In this study, we also saw that there was no significant difference between the BPPV group and the control in the number of falls after treatment with CRPs. However, in this study, there was also no significant difference in fall history beforehand, so we cannot speak so much as a decrease in the number of falls. Dynamic balance has an important role in fall prevention, but in older adults, it takes longer to restore this dynamic balance (Chen et al., 2016). Due to the short follow-up of this study, we may not have found a treatment effect of the TUG because dynamic balance did not have enough time to recover. Persons with more fear of falling (higher score on the FES) were likelier to experience falls than those without (Canever et al., 2022; Gazibara et al., 2017). Pauwels et al. (2023) showed that fall incidence, number of falls, and fear of falling reduced after treatment. But despite this improvement in fear of falling, people with BPPV were still afraid to trigger symptoms with head movements.

This study found no difference in the degree of depressive feelings when comparing the BPPV with the control group. Ketola et al. (2007) found that nearly 20% of vertiginous patients also have depressive symptoms, with the incidence being higher in women than men. Why no significant difference was found in our study may possibly be because some controls also experienced dizziness, and Ketola et al. (2007) examined not only patients with BPPV but also other vertiginous disorders.

If people begin to recognize undiagnosed BPPV (Hawke et al., 2017) more quickly and have a better understanding of BPPV, effective treatment can be applied more quickly (Jumani & Powell, 2017).

Critical reflection

The sample size of this study was smaller than previously calculated because recruiting participants was more difficult than expected. This makes the results less reliable for drawing conclusions from a diverse population. However, The control and BPPV groups could be well-matched based on the predetermined characteristics. The participants with BPPV in this study had predominantly posterior canal BPPV, for which classification of results by type of BPPV was not feasible. Therefore, the results of this study may also be less representative of patients with anterior or lateral canal BPPV, however, the largest proportion within the BPPV population has posterior canal BPPV (Parnes et al., 2003), so it also would not have been representative if more participants with anterior or horizontal canal BPPV were included in this study

In many aspects, a longer follow-up period than one month may be recommended (Ke et al., 2022). More significant or other results could be found when re-evaluating three or even six months post-treatment. The recurrence of BPPV and residual dizziness could also be evaluated by then (Da Silva et al., 2015). This longer follow-up period does exist in the larger study.

Because this study only evaluates a part of the larger study, we regularly discuss matters that have been investigated before. However, having an increased risk of falling and how much it is increased has been little studied until now. We found that the number of people with increased fall risk was significantly higher in the BPPV group than in the control group and that this difference was not present anymore after treatment. In the larger study, many more balance parameters and the activity level of each participant are examined. This could lead to more new results that were not previously discussed. For example, the large study further examines physical activity, possibly associated with an increased risk of falling (Agrawal et al., 2013; Liao et al., 2015; Neuhauser, 2016). The results that were found were mostly in good agreement or consistent with studies that were being conducted in the past.

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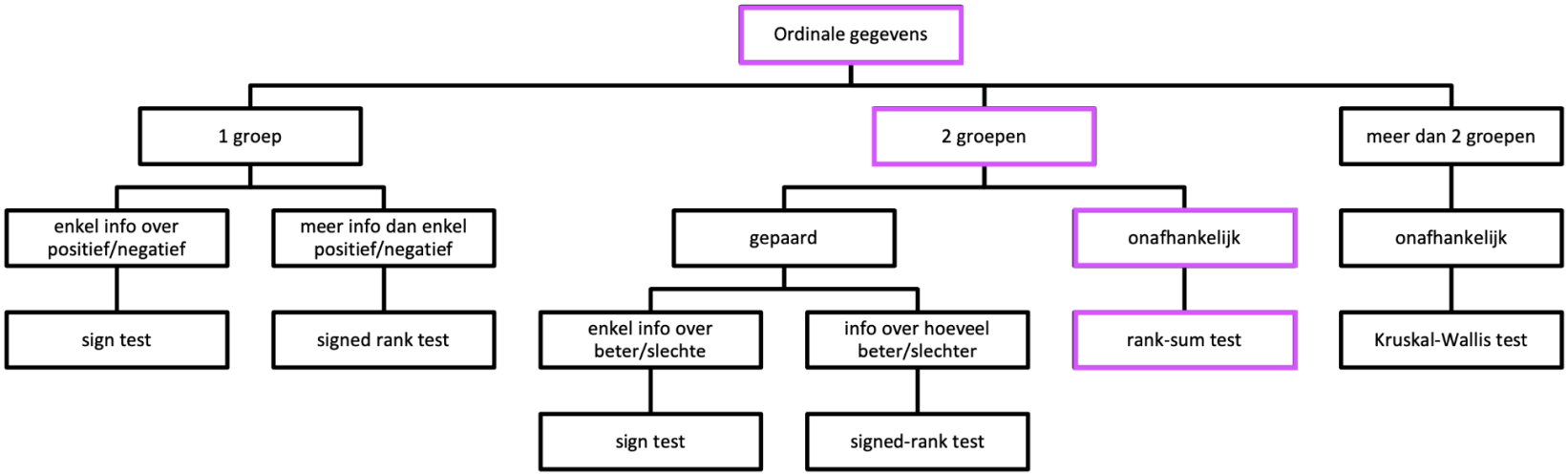
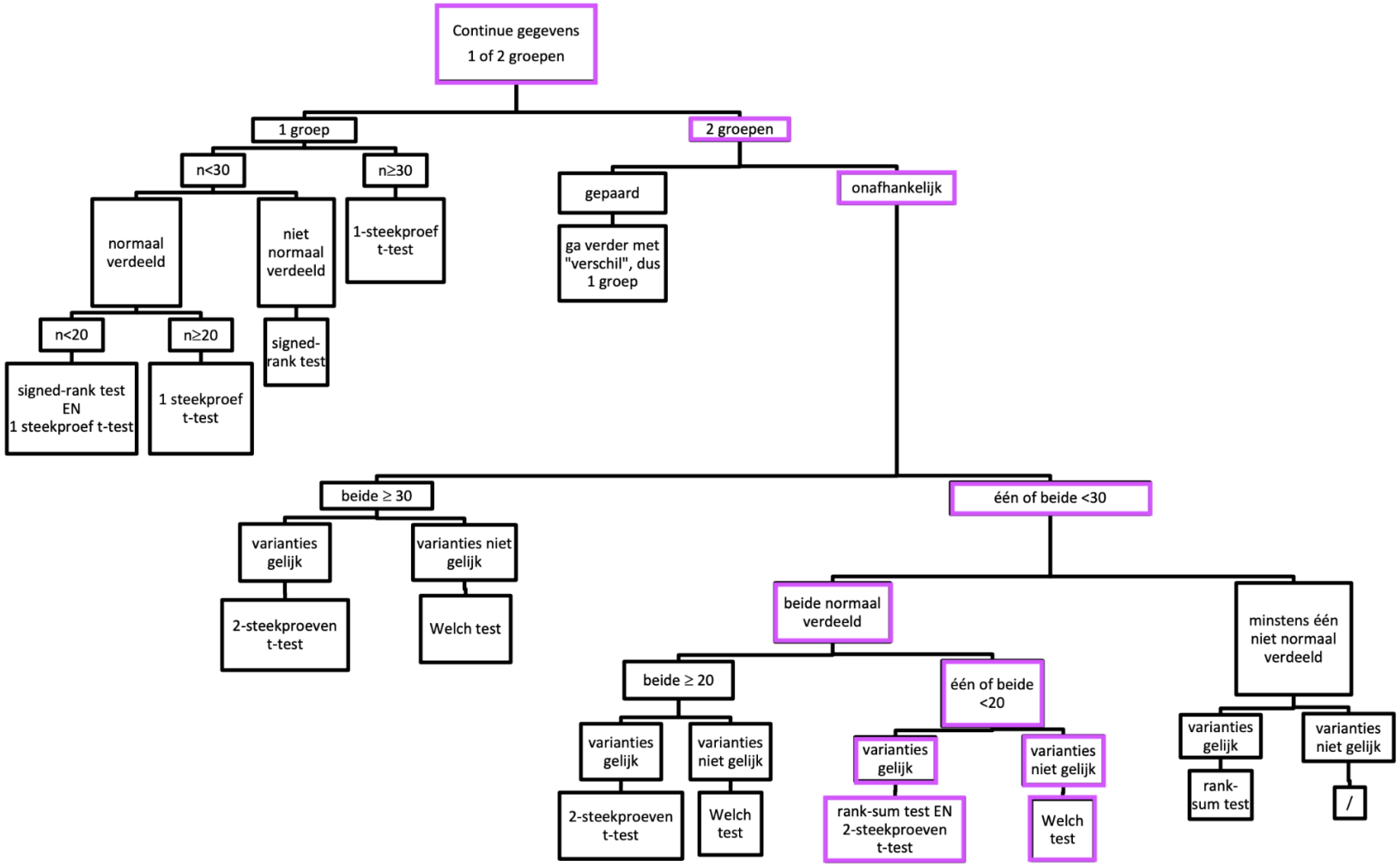
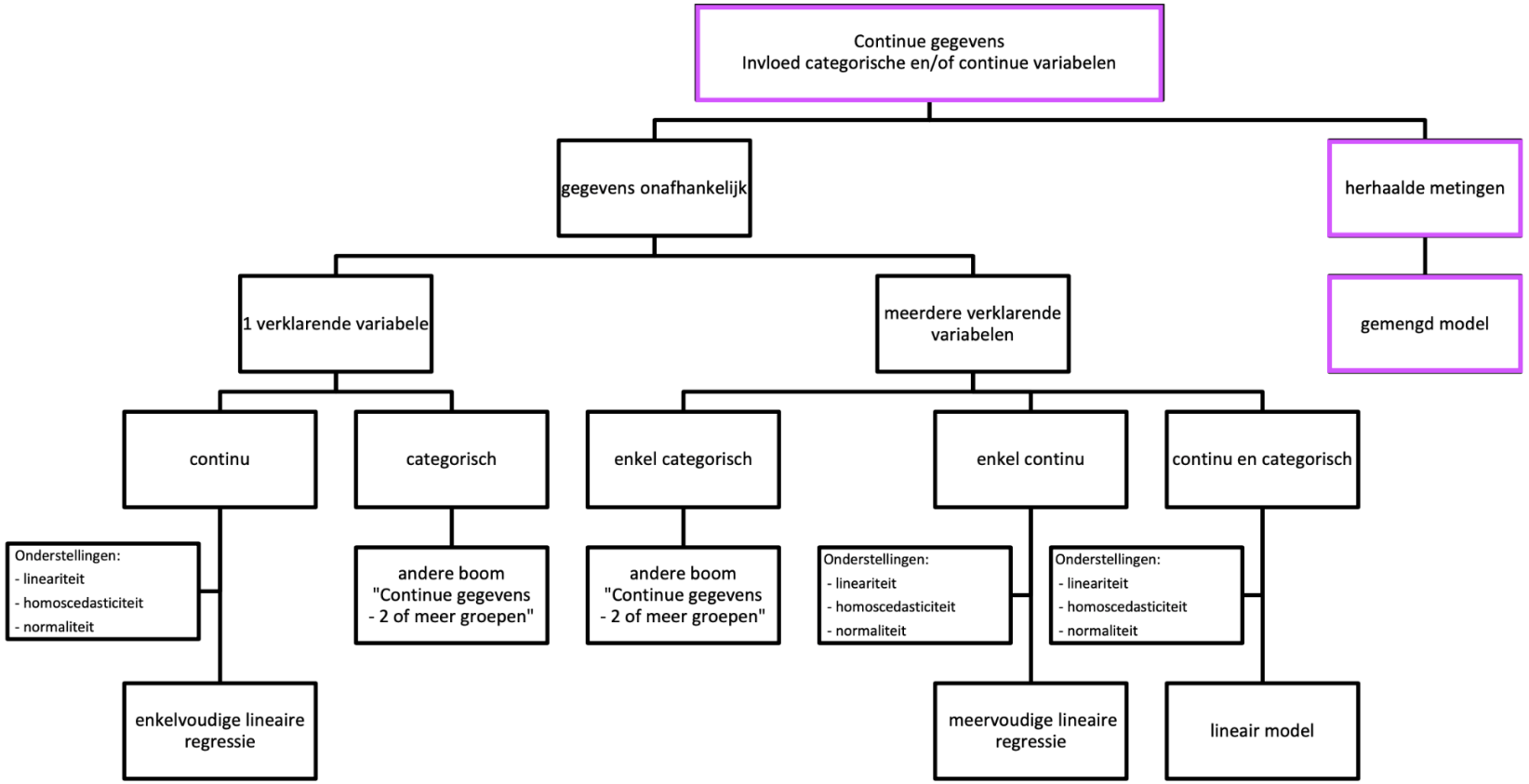
Attachments

Appendix 1 - Decision Trees




Continue gegevens
1 of 2 groepen
1 groep
2 groepen
n<30
n≥30
gepaard
onafhankelijk
normaal verdeeld
niet normaal verdeeld
1-steekproef t-test
ga verder met "verschil", dus 1 groep
n<20
n≥20
signed-rank test
signed-rank test EN 1 steekproef t-test
1 steekproef t-test
beide ≥ 30
één of beide <30
varianties gelijk
varianties niet gelijk
2-steekproeven t-test
Welch test
beide normaal verdeeld
minstens één niet normaal verdeeld
beide ≥ 20
één of beide <20
varianties gelijk
varianties niet gelijk
2-steekproeven t-test
Welch test
varianties gelijk
varianties niet gelijk
rank-sum test EN 2-steekproeven t-test
Welch test
varianties gelijk
varianties niet gelijk
rank-sum test
/


Continue gegevens
Invloed categorische en/of continue variabelen
gegevens onafhankelijk
herhaalde metingen
1 verklarende variabele
meerdere verklarende variabelen
gemengd model
continu
categorisch
enkel categorisch
enkel continu
continu en categorisch
Onderstellingen:
- lineariteit
- homoscedasticiteit
- normaliteit
andere boom
"Continue gegevens
- 2 of meer groepen"
andere boom
"Continue gegevens
- 2 of meer groepen"
Onderstellingen:
- lineariteit
- homoscedasticiteit
- normaliteit
Onderstellingen:
- lineariteit
- homoscedasticiteit
- normaliteit
enkelvoudige lineaire regressie
meervoudige lineaire regressie
lineair model