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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Association between Benign Paroxysmal Positional Vertigo and underlying vestibular disorders in older adults on different outcomes measures

Maria Fernanda Becerra Ospino
Dorien Boeckmans

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

PROMOTOR :

Prof. dr. Joke SPILDOOREN

BEGELEIDER :

Mevrouw Sara PAUWELS

2023
2024

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Context

Older adults are more prone to gait and balance disabilities, which can be attributed to both age-related changes and an increased prevalence of certain medical conditions. Conditions such as Benign Positional Paroxysmal Vertigo and unilateral vestibular hypofunction can alter balance in these individuals. This alteration can lead to more frequent falls, an elevated risk of injuries and frailty. As a result, older adults may find it more difficult to manage daily activities and engage in social life, leading to a decline in quality of life and increased incidence of depression. When these factors are combined, they can create a significant issue. Therefore, can the presence of multiple vestibular disorders potentially worsen the overall condition?

This experimental study article is a part of a broader investigation of the PhD Sara Pauwels under the guidance of Prof. dr. Joke Spildooren. At the same time, this study is the thesis of Maria Fernanda Becerra Ospino and Dorien Boeckmans, two students' masters in the rehabilitation sciences and physiotherapy from the University of Hasselt.

The investigation will be employed in the hospital Oost-Limburg (ZOL) where the material has been made available to facilitate the necessary tests including caloric irrigation test, as well as various assessments and treatment maneuvers.

The research question of this duo-thesis article will be made by the two students in agreement with the PhD student. During the first master year, the students could assist Sara Pauwels with the assessment of the participants for this greater investigation.

Abstract

Background: Older adults encounter greater disabilities due to Benign Paroxysmal Positional Vertigo (BPPV) and unilateral vestibular hypofunction (UVH), but the relationship and consequences between these remain unclear.

Objectives: This study investigated differences between older adults diagnosed with BPPV (OABPPV) and those with an extra underlying vestibular disorder, specifically identified through a positive score on the caloric test (OABPPV+), across various outcomes.

Methods: Older adults (64+) were diagnosed with BPPV and treated targeting the affected canal using particle repositioning maneuvers (PRM). Participants were evaluated on different outcomes: Mini-BESTest, Fried's phenotype, falls history, FES, DHI, GDS-15 and number of treatments received. Vestibular function was assessed using the caloric irrigation test.

Results: The OABPPV (n=21) was compared with the OABPPV+ (n=10). Demographically, both groups were similar except for gender, with a higher prevalence of women in the OABPPV+ (p=0.05). Postural control revealed significantly better sensory orientation in the OABPPV compared to OABPPV+ (p<.001), with trends observed in other postural control metrics. There were no significant differences on the other outcomes.

Conclusion: The hypothesis, suggesting that OABPPV+ would exhibit poorer performances across all outcome measures, can be refuted based on our findings. However, OABPPV+ persists with more impairments on postural control than OABPPV. It is necessary to analyze the greater picture of the primary research and possibly other future studies about this topic. Clinicians have to be aware of the possibility that BPPV can occur with an extra underlying vestibular disorder.

Keywords: *benign paroxysmal positional vertigo, unilateral vestibular hypofunction, older adults, postural control, falls, frailty, subjective well-being, number of treatments*

Association Between Benign Paroxysmal Positional Vertigo And Underlying Vestibular Disorders In Older Adults On Different Outcomes Measures.

Introduction

BPPV is the most prevalent disorder of the peripheral vestibular end-organ, manifested by recurrent episodes of a spinning sensation induced by positional changes of the head with respect to gravity. BPPV has a 2.4% lifetime prevalence and an annual estimated prevalence of approximately 10.7-140 per 100.000 citizens (Bhattacharyya et al., 2017; Kim & Zee, 2014; You et al., 2019). The highest occurrence typically manifests in individuals between the age of 50 and 60, women being 2-3 times more affected than men (Kim & Zee, 2014; You et al., 2019). BPPV is provoked by the displacement of otoconia from the macula of the utricular otolith, causing them to enter the semi-circular canals. This will cause a distorted signaling to the brain, giving rise to a false perception of motion perceived by the patient (You et al., 2019). Posterior canal BPPV is the most frequent diagnosis reported in 80% to 95% of the cases. Horizontal canal BPPV is reported in 5% to 22% of the cases (Bhattacharyya et al., 2017; You et al., 2019). Symptoms may vary in intensity, ranging from mild dizziness and unsteadiness to severe episodes that can induce nausea and vomiting, subsequently impairing daily functioning (Bhattacharyya et al., 2017; Kim & Zee, 2014; Mandala et al., 2019).

UVH is characterized by partial or complete functional impairment in one of the peripheral vestibular organs and/or vestibular nerves. This can result from trauma, after surgical interventions, Meniere's disease and vestibular neuritis (Hall et al., 2022). Vertigo, dizziness, nausea, postural instability, visual or gaze disturbances and spontaneous nystagmus are symptoms experienced by individuals due to this asymmetry in resting vestibular tone (Edwards & Franklin, 2024; Hall et al., 2022). The caloric irrigation test, as a standard test, can determine the presence of UVH (van Esch et al., 2016).

However, BPPV is most frequent to have an idiopathic origin, there are a number of conditions impacting the peripheral vestibular system that may precede the onset of BPPV (Pollak et al., 2002). In Bhattacharyya et al. (2017), BPPV has been found associated with underlying vestibulopathy by 31% to 53% of BPPV patients. Besides this, Zhu et al. (2019) affirms that BPPV coexists with other vestibular diseases. This can be attributed to the fact that BPPV causes damage to the utricle provoking the detachment of the otoconia leading to different inner ear problems.

The symptoms associated with peripheral vestibular dysfunction commonly result in chronic and disabling conditions (McDonnell & Hillier, 2015). Especially in older adults experiencing dizziness, the risk of falls and injuries increases (Hall et al., 2022; Iwasaki & Yamasoba, 2015). At the same time, this is also associated with postural imbalance and fear of falling (Edwards & Franklin, 2024).

Falls contribute to one of the most common causes of death in the older population. The worldwide prevalence of falls in the older population is estimated to be 26.5% (Salari et al., 2022). Based on the systematic review of Donovan et al. (2023) more than 50% of people who fall have a vestibular dysfunction. The presence of BPPV increases the odds of falls, as suggested by Pauwels et al. (2023). Additional contributing factors to falls encompass frailty and postural control (Osoba et al., 2019; Taguchi et al., 2022)

Frailty is a clinical state marked by increased vulnerability due to age-related decline in reserve and functions across multiple physiological systems, leading to diminished ability to handle acute stressors (Xue, 2011). It is defined by meeting three out of five phenotypic criteria of Fried which are: unintentional weight loss, self-reported exhaustion, weakness, slow walking speed and low physical activity (Fried et al., 2001). These factors contribute to an elevated risk of falls, especially in older adults (Taguchi et al., 2022). The study of Gomez et al. (2011) observed that older individuals who report dizziness tend to be more physically frail.

Postural control refers to the ability to maintain stability in a specific posture (Mancini et al., 2020). Horak et al. (2009) defines postural control as an interaction between different systems. Including: biomechanical systems, limits of stability, anticipatory postural adjustments, sensory integration and dynamic balance during gait. The Balance Evaluation System Test (BESTest) takes these systems into account. Age-related changes in postural control such as declining balance, decreased postural stability, increased postural sway, and a reduced ability to adapt to new sensory information, all contribute to an increased risk of falls in older adults (Osoba et al., 2019). Older adults with BPPV experience body imbalance due to functional impairments (Vaz et al., 2013). These impairments can lead to a greater likelihood of categorizing this population as frail (Moraes et al., 2019).

Subjective well-being lacks a definition, yet objective conditions such as health influences it (Diener et al.,1997 cited in (Angner, 2010). A reciprocal interaction has been observed between frailty and depression in older people, each increasing the likelihood of the other's incidence and prevalence (Soysal et al., 2017). In conjunction, frailty and fear of falling are associated in elderly community-dwelling people (de Souza et al., 2022). In older adults with BPPV the successfulness of repositioning maneuvers is predicted by dizziness levels, and a DHI score of ≥16 suggests residual dizziness. Other factors that predict residual dizziness are anxiety and depression (Sun et al., 2023). The research of McKay et al. (2022) quotes that being frail, having depression, being afraid of falling, are all linked with a lower physical and mental health-related quality of life.

Number of treatments for BPPV patients to recover is also a concerning outcome. Older adults have a higher recurrence rate and need more particle repositioning maneuvers (PRM) compared to younger adults (Laurent et al., 2022). The frequency and rate of recurrence seems to be higher in individuals afflicted by this disease in combination with another peripheral vestibular disorder (Zhu et al., 2019).

Considering the possible relation between BPPV and vestibular disorders, as well as the consequences of these disorders in older adults on daily life. The aim of this study is to investigate what is the impact of underlying vestibular disorders on older adults with BPPV on balance, frailty, falls, sense of well-being, and the number of treatments they require. It is hypothesized that older adults with BPPV and an underlying vestibular disorder may encounter more difficulties maintaining balance, frequent falls, face heightened levels of anxiety and depression, be more likely to be classified as frail and receive a greater number of treatments.

Methods

Ethical committee

This study was conducted according to the Declaration of Helsinki (2013). The study protocol was approved by the Medical Ethics Committees of ZOL hospital and UHasselt (B3712021000013) in Belgium. Informed consent was provided by all study participants.

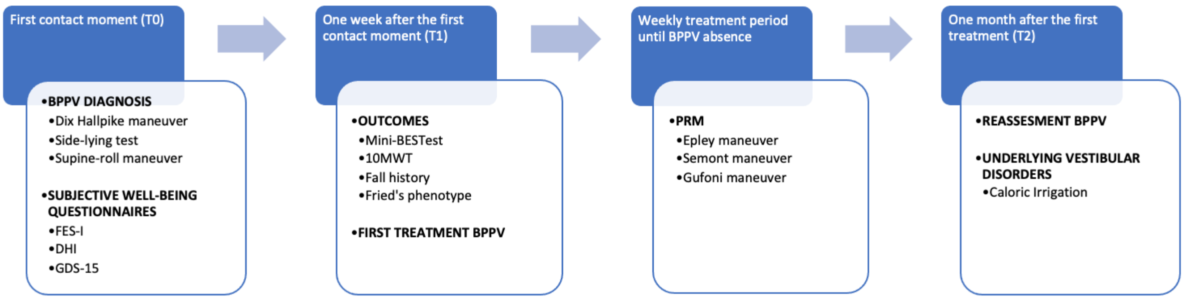
Participants

The participants were recruited at the ear, nose and throat department (ENT) of the hospital Oost-Limburg (ZOL) in Genk. Criteria for selecting participants were as follows: ≥ 65 years old, able to stand independent for minimal 30 seconds, able to walk (with or without walking aid) for minimally 10 meters, and acute primary symptoms of BPPV in posterior semi-circular canal or lateral semi-circular canal. The exclusion criteria were: unable to understand and follow simple instructions, persons living in a residential or psychiatric care center (temporary or permanently), persons with contra-indications for the diagnostic maneuver of the caloric irrigation test, persons with evolutionary disorder of the central nervous system, persons who were still in a rehabilitation phase after an orthopedic or cardiovascular incident and if they have had an spontaneous resolution of BPPV before the measurement was completed.

Testing procedure and outcomes

Figure 1

Timeline Testing Procedure, Treatment and Outcomes

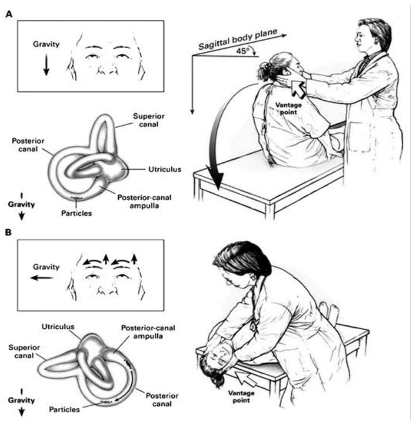


Note. BPPV Benign Paroxysmal Positional Vertigo, FES-I Falls Efficacy Scale International, DHI Dizziness Handicap Inventory, GDS-15 Geriatric Depression Scale, Mini-BESTest Mini Balance Evaluation System Test, 10MWT 10 Meter Walk Test, PRM Particle Repositioning Maneuvers.

Diagnosis of BPPV was confirmed with video-frenzel at the vestibular department by researcher Sara Pauwels or audiologist at ZOL on the first contact moment (T0). The Dix-Hallpike maneuver *(figure 2)* was performed to investigate the posterior semi-circular canal. The first step involved the seated patient turning its head 45 degrees to the right, aligning the right posterior semi-circular canal with the sagittal plane of the body. Then the patient was brought into supine position, extending the neck and holding this posture over the edge of the examination table. The researcher evaluated the duration, latency and direction of the nystagmus and asked the patient for symptoms of dizziness. A positive nystagmus for posterior semi-circular canal BPPV was characterized by being upbeating and torsional. Finally, the patient returned to sitting position. This maneuver was repeated for the left side as well (Bhattacharyya et al., 2017).

Figure 2

Dix-Hallpike Testing Maneuver

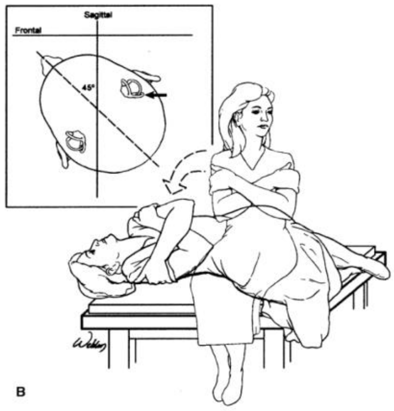


Note. Reference: (Bhattacharyya et al., 2017).

In case of contra-indications such as limited range of motion, the Side-lying test *(figure 3)* was conducted as an alternative to the Dix-Hallpike maneuver. To execute this test, the seated patient rotated the head 45 degrees away from the tested ear, aligning the posterior canal with the frontal plane. Afterwards, the patient was brought into a side-lying position on the tested side and held this position for approximately two minutes. Finally, the patient returned to the upright position. This technique was repeated for the opposite side as well (Cohen, 2004).

Figure 3

Side-Lying Test

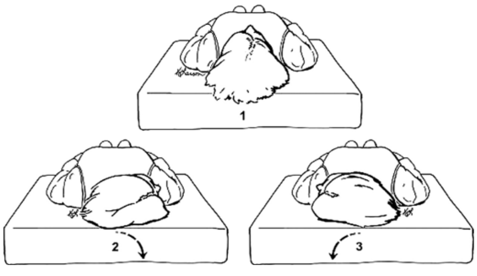


Note. Reference: (Cohen, 2004).

The lateral canal was evaluated with the Supine-Roll maneuver *(figure 4)* where the patient already lay on the back with the head flexed in 30 degrees looking upwards. The researcher rapidly rotated the head 90 degrees to the right while observing the appearance of the nystagmus. When the nystagmus decreased, the head was turned back to the midline and then rotated to the left side, again in anticipation of the nystagmus. There were 2 types of lateral canal BPPV that could be determined: geotropic type when the nystagmus beats in the direction of the earth, the side with the strongest nystagmus was also the affected ear and ageotropic type when the nystagmus beats towards the uppermost ear, the affected ear is the side opposite to the one with the strongest nystagmus (Bhattacharyya et al., 2017).

Figure 4

Supine Roll Testing Maneuver



Note. Reference: (Bhattacharyya et al., 2017).

To assess subjective well-being, three questionnaires were given to the participants to fill out at home. The first set of questions was the Falls Efficacy Scale International (FES-I). This questionnaire allowed us to have an illustration of the fear of falling that participants could experience by answering *"how concerned are you about the possibility of falling"* on the 16 different daily life and social activities. The score range goes from *"1 = Not concerned at all"* to *"4 = really concerned"* of falling. The total score goes from 16 to 64 points (Morgan et al., 2013). The Dizziness Handicap Inventory (DHI) is a self-reported questionnaire to evaluate the impact of dizziness on daily living. The 25 items are categorized into three subscales: functional (9 items), emotional (9 items) and physical (7 items) aspects of dizziness. For each question, the following scores can be assigned: *No = 0; sometimes = 2; and yes = 4* ((Jacobson & Newman, 1990). Total score ranges from 0 to 100 meaning that a higher score corresponds to an increased perception of handicap (Vereeck et al., 2006). Lastly, the Geriatric Depression Scale (GDS-15) accustomed measurement of depressive feelings on older adults based on 15 yes/no questions (Shimada et al., 2014).

Maximum one week after the first contact moment (T1), participants were evaluated for the outcomes described below and were treated for the respective BPPV diagnosis.

To evaluate postural control, the Mini Balance Evaluation System test (Mini-BESTest) was used. The Mini-BESTest contains 14 items grouped in 4 sections: anticipatory postural changes, reactive postural control, sensory orientation and stability in gait, which are scored on a 3-point scale (Viveiro et al., 2019). Furthermore, the walking speed was assessed during the 10-Meter Walk Test. The walking distance needed for this test is 20 meters where five meters was used for acceleration and the last five meters for deceleration (Peters et al., 2013). Data were collected with the aid of Mobility lab - ADPM-sensors. These sensors were attached to the feet and the average was calculated for the right and left foot respectively. Both balance and walking speed assessments were evaluated without walking aid.

To determine frailty, the Fried's phenotype was used (Fried et al., 2001). The five components of this phenotype were adjusted by Avila-Funes et al. (2008) and are assessed as follows: 1) Recent and unintentional weight loss was questioned by *"Did you unintentionally lose 3 kilograms or more of your body weight?"* and besides, body mass index (BMI) was calculated. A *"yes"* answer and a < 21kg/m2 BMI was regarded to be frail for this item. 2) Perceived exhaustion was assessed by *"I felt that everything I did was an effort*" and *"I could not get going"* followed by the question *"How often in the last week did you feel this way?".*

The participants could answer: *0 = rarely or none of the time (> 1 day); 1 = some or little of the time (1-2 days); 2 = a moderate amount of the time (3-4 days);* or *3 = most of the time (5-7 days)*. Answers *"2"* or *"3"* were regarded to be frail for this item. 3) Walking speed was calculated based on the 10-meter walk test. 4) Functional strength was evaluated by the question: *"Do you have trouble standing up from a chair?"*. A *"yes"* answer was regarded to be frail for this item. 5) Physical activity was questioned by *"Do you regularly perform physical activities such as gardening, walking or sports?"*. A *"no"* answer was regarded to be frail for this item. Based on this information, participants were considered to be "frail" having three or more frailty components, further categorization was "pre-frail" having one or two and "non-frail" if none of the criteria were met (Avila-Funes et al., 2008; Fried et al., 2001)

Fall history was questioned by *"Have you fallen in the past months?"*. Then, the number of falls by asking "*how often did this happen?"* and lastly the cause behind the fall was investigated by *"was this accidentally, unknown, due to dizziness or due to syncope?"*.

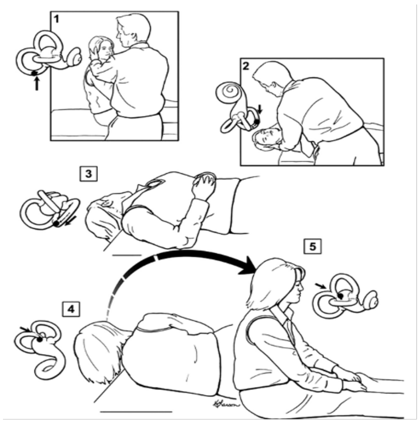
Treatment procedure

Once the diagnosis was established, the patients were treated with the PRM for the affected canal. After the first PRM, a re-evaluation will be managed using the diagnostic maneuver along with video-frenzel to assess the persistence of the nystagmus. If this is the case, a second PRM-cycle was administered in case of posterior canal BPPV. This process was repeated every week until presenter-evaluation was negative. The number of treatment sessions was compared between OABPPV and OABPPV+.

The Epley maneuver *(figure 5)* was performed for the repositioning of the particles in the posterior semi-circular canal or canalolithiasis. The patient was seated with extended legs on the examination table. The researcher held the patient's head rotated 45 degrees to the direction of the affected side, then the patient quickly lay on the back with the head hanging over the edge of the table. Subsequently, the head was turned to the unaffected side maintaining 45 degrees and afterwards the patient lay on this side too so the head will almost face down. To complete the maneuver, the patient was sitting back vertically. Every position was moreover held until at least 30 seconds after the nystagmus disappeared (Bhattacharyya et al., 2017).

Figure 5

Epley Maneuver

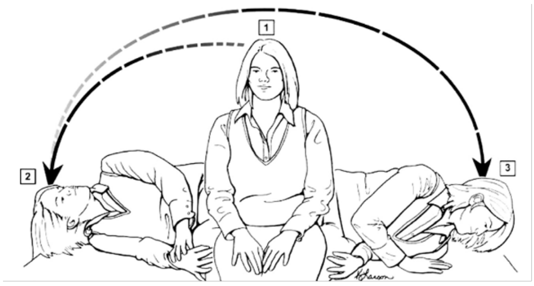


Note. Reference: (Bhattacharyya et al., 2017).

Furthermore, when this technique was not possible to achieve for the patient, the Semont maneuver *(figure 6)* was used. The sitting patient rotated the head 45 degrees away from the affected side and quickly lay on the affected side, the head will face upwards. Then a swiftly transition to the opposite side-lying position (180 degrees arc) maintaining the head in the same way but now looking downwards. Next, the patient returned to the sitting position. Every position was held until at least 30 seconds after the nystagmus disappeared (Bhattacharyya et al., 2017).

Figure 6

Semont Maneuver

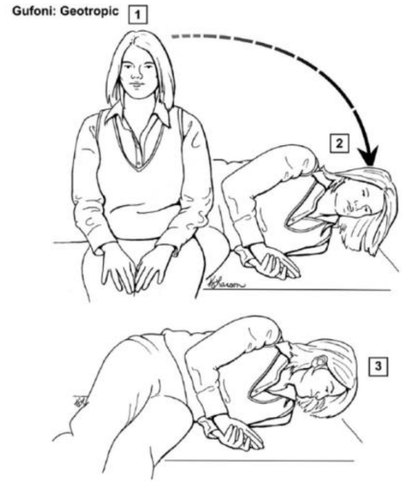


Note. Reference: (Bhattacharyya et al., 2017).

The lateral semi-circular canal was treated with the Gufoni maneuver. Geotropic lateral canal BPPV was treated using de geotropic gufoni *(figure 7)*. The sitting patient was guided by the researcher to lie on the unaffected side; this position was held until the geotropic nystagmus had ceased. Then the head was rapidly rotated facing the ground by 45 degrees and kept in this position for two to three minutes approximately. Finally, the patient could sit again (Bhattacharyya et al., 2017).

Figure 7

Geotropic Gufoni Maneuver

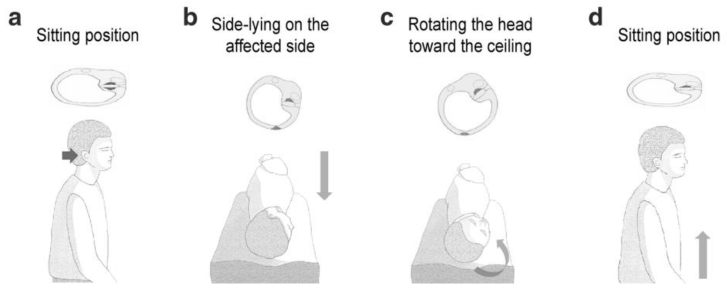


Note. Reference: (Bhattacharyya et al., 2017).

Ageotropic lateral canal BPPV was treated using de ageotropic gufoni *(figure 8)*. On this technique the sitting patient lay on the shoulder of the affected side and maintained this position until the ageotropic nystagmus ceased. Afterwards the head is turned towards the ceiling and again held for two minutes in the same position. The patient is brought back to the upright position (Kim et al., 2017).

Figure 8

Ageotropic Gufoni Maneuver



Note. Reference: (Kim et al., 2017).

One month after the first treatment (T2), the presence of BPPV was re-evaluated with video-frenzel and if necessary, treated according to the affected canal. Subsequently, the participants were tested for underlying vestibular disorders with the caloric irrigation test. For this procedure, sterilized water was applied on 44° (warm water irrigation) and 30° (cool-water irrigation) directly into the patient's ear channel during 30 seconds and alternating both sides (Shepard & Jacobson, 2016). After the irrigation, the duration of the nystagmus was measured in the presence and absence of optic fixation with the aid of video-frenzel (Pollak et al., 2002). The Jongkees formula was utilized to express vestibular hypofunction. Based on the maximum slow phase velocities (SPV) of the nystagmus beat, this formula was used: (R30° + R44°) − (L30° + L44°) / (R30° + R44° + L30° + L44°) × 100 = % (Olivecrona et al., 2022; Wexler, 1994). UVH was eventually determined if there was 25% of asymmetry between the right and left ear and/ or the sum of SPV was below 15 degrees per vestibular system (Olivecrona et al., 2022). The results from the caloric irrigation test were employed to distribute the participants into two different groups, thereby a group with a positive score and another with a negative score.

Statistical analysis

JMP Pro 16 was used for statistical analyses. Shapiro-wilk determined the normality of the data. The results were compared with the Fisher's exact test for categorical data or the independent t-test for parametric continuous data. A non-parametric test, the Wilcoxon rank sum test, was used for non-normal distributed data. $\alpha = 0.05$ was set as the level of significance.

The holm-bonferroni method was used to correct for the conduction of multiple testing. Thereby achieving a reduction in type I error, thus minimizing the possibility of a false significant result. This was accomplished by grouping the different outcome measurements. Variables of the Mini-BESTest and its subscales along with the 10 meter walk test were grouped for the outcome balance. Then, frailty and its subscales were grouped for the outcome frailty. Lastly the different questionnaires such as DHI and its subscales, FES-I and the GDS for the outcome subjective well-being. For each of these groups the p-values were ranked from smallest to largest. Considering the number of tests conducted, an alternative p-value could be established using the Holm-Bonferroni formula (*figure 9*). This formula incorporates the target α at 0.05, 'm' as the total number of tests conducted, and 'i' representing the position the p-value held in the ranking (Chen et al., 2017).

Figure 9

Holm-Bonferroni Formula

$$\alpha'_{(i)} = \frac{\alpha}{m - i + 1}$$

Note. Reference: (Chen et al., 2017).

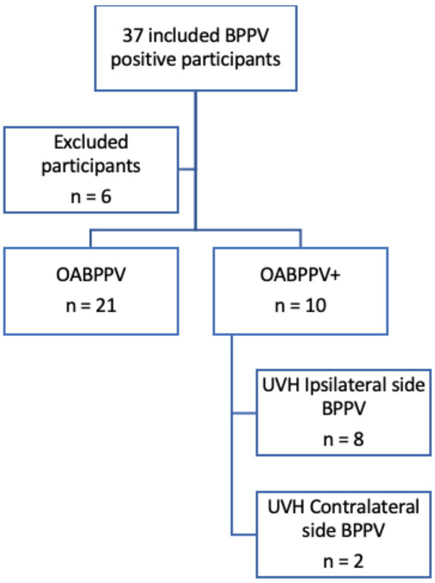
Since we focused on a subset of variables that are part of a greater investigation, no a priori power analysis was performed. However, a comprehensive sensitivity analysis may possibly be undertaken in the broader research.

Results

For this study, 37 patients were diagnosed with BPPV. However, six patients were excluded due to missing or unreliable data from the caloric irrigation test, preventing their categorization. Eventually, 31 BPPV patients were divided into two groups: older adults diagnosed with only BPPV (OABPPV) (n=21) and older adults with an underlying vestibular disorder, specifically those with a positive score on the caloric irrigation test (OABPPV+) (n=10). In OABPPV+ eight participants had UVH at the ipsilateral side, while two participants had UVH on the contralateral side as illustrated in figure 10.

Figure 10:

Flowchart Of The Classification Of The Groups



Note. Caloric test positive participants on OABPPV+ and side of BPPV diagnosis are mentioned.

Characteristics

There were no significant differences in the demographic characteristics between the two groups, except for gender (*table 1*). In OABPPV+, women were more prevalent (p=0.05). All walking aids were already used prior to the presence of BPPV.

Postural control

Results and p-values are presented in table 2 and figure 11. For outcome balance the OABPPV has a significantly better sensory orientation than the OABPPV+ (<.001). A trend was observed for the items of gait, anticipatory postural changes, total score of the Mini-BESTest and 10 meter walk test. No significant difference was established for reactive postural control.

Frailty

Contrary to our hypothesis, the OABPPV+ was not more frail than the OABPPV. No significant differences were perceived at any subdomains of the Fried criteria. For determining the frailty status one participant had to be excluded due to missing data (exhaustion, weakness, physical inactivity).

Falls

There was no significant difference in the outcome falls between the OABPPV and OABPPV+. There were no discrepancies in history, number of falls or causes of these falls.

Sense of well-being

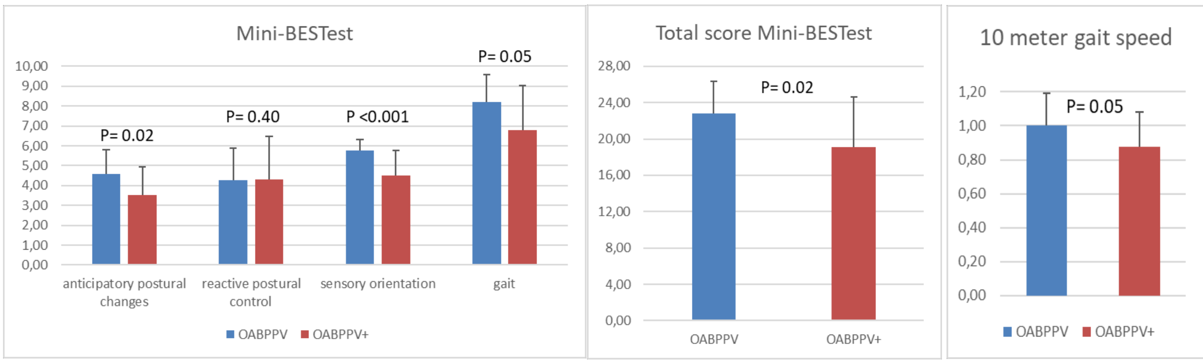
As can be seen from table 2, the sense of well-being has shown no significant difference between the two groups. The OABPPV+ does not experience greater deprivation as measured by the GDS-15, furthermore there is no increased fear of falling as measured by the FES-I, nor was there any heightened disability due to dizziness on any subscale or total score as according to the DHI.

Number of treatments

Further on, the number of treatments was not significantly different. The OABPPV+ does not need more treatment sessions than the OABPPV. Whether the participant persisted with BPPV or not at T2 proved no significant difference between the two groups.

Figure 11:

Mean And Standard Seviations For The Different Outcomes



Discussion

This study aimed to investigate the influence of underlying vestibular disorders alongside BPPV and its effect on balance, subjective well-being, frailty, falls and number of treatments required. As far as we know, this study is the first to investigate the effect of an underlying vestibular disorder on these various outcomes in older adults affected with BPPV.

Based on the findings of this study, the results of the following subsets of the Mini-BESTest initially showed significant results: gait, anticipatory postural changes and total score. However, after applying the Holm-Bonferroni correction, these were no longer evident. An increased risk of falls is indicated by the cut-off score of <19 on the Mini-BESTest, depending on the published study (Di Carlo et al., 2016). The mean total score of OABPPV+ was 19.10 which is relatively close to this cut-off, suggesting that the OABPPV+ has an elevated risk of falls compared to OABPPV. Furthermore, OABPPV+ exhibit a lower mean score on gait and anticipatory postural changes compared to OABPPV. This discrepancy can be attributed to the additional senses of dizziness caused by UVH, such as: disequilibrium and oscillopsia. In contrast, individuals with BPPV only experience vertigo. Another reason could be that patients with acute UVH exhibit a noticeably altered gait pattern, unlike patients with BPPV, who maintain a normal gait. During the acute phase of UVH, walking while turning the head challenges balance, whereas BPPV patients may only experience mild unsteadiness. Additionally, while patients with BPPV can perform a single-leg stance, those with UVH might struggle to maintain this position (O'Sullivan et al., 2019). Besides, age-related factors must not be underestimated and this could also explain why these values fail to reach statistical significance (Osoba et al., 2019). For the subset sensory orientation, individuals diagnosed with OABPPV+ exhibit a diminished sensory orientation compared to OABPPV. This could be due to the fact that the vestibular system, essential for postural stability in absence of visual and somatosensory input, becomes less responsive in BPPV, which contributes to postural instability (Nasruddin, 2022). The sensory orientation in patients with UVH seems to be more problematic when the proprioceptive system is disturbed in contrast to the visual system. Compared to controls, UVH patients have more difficulty to maintain postural control when vision and proprioception are disrupted (Eysel-Gosepath et al., 2016). It may be suspected that individuals affected by BPPV and an underlying vestibular disorder rely even more on these other systems to maintain postural stability.

Similar to the Mini-BESTest, a trend was established on the results of the 10MWT. The velocity of both groups was found to be below the normative values of gait speed among healthy older adults. Based on European values identified in the study of Andrews et al. (2023), healthy older adults with ages ranging from 60-80+ years old had a mean score of 1.15m/s and 1.22m/s for women and men, respectively. In another research, a mean velocity of 1.43 m/s was found among healthy older adults with a mean age of 74.9 years (Saito et al., 2022). Additionally, values from the research of Zhang et al. (2021) showed a difference between healthy controls and BPPV. A mean gait speed of 1.12 m/s and 1.20 m/s for BPPV and healthy subjects was found among adults with ages ranging from 25-70 years old. In the current study we found mean values of 1.00 m/s for OABPPV and 0.88 m/s for OABPPV+. This finding suggests that the involvement of the vestibular organ may have a major influence on walking speed.

Comparing our findings with the study of Kabaya et al. (2023), we observed a discrepancy in the timing of the caloric irrigation test assessment. Whilst they performed the test at diagnosis, we conducted it one month after the first treatment. In our research, we included 10 (32.3%) participants with canal paresis. Among participants with lateral canal BPPV, 40% exhibited an abnormal caloric irrigation test, whereas for those with posterior canal BPPV, the percentage was slightly lower at 38.1%. Kabaya et al. (2023) found the caloric irrigation test to be abnormal in 66.7% of individuals who suffer from horizontal BPPV and 33.3% in posterior BPPV. Typically, canal paresis occurs on the ipsilateral side of the BPPV. In comparison to our study, we also found that the majority (eight out of ten) of the participants with UVH had BPPV on the ipsilateral side and two on the contralateral side. We must be aware of the fact that the abnormal scores in Kabaya et al. (2023) could be false positive caloric test results, due to the time of conduction. They claim that the degree of caloric hyperexcitability in the lateral semi-circular canal might be influenced by both the size and amount of dislodged debris present in the affected canals. In posterior BPPV patients, hyperesthesia may arise due to the repeated movement of the otoconia within the ipsilateral posterior semi-circular canal, giving rise to caloric weakness (Kabaya et al., 2023). Additionally, the presence of otoconia in the endolymph of the lateral semi-circular canal adds a gravitational load to the fluid, which can impact the caloric response (Korres et al., 2004). Yetiser and Ince (2017) also established how the otoconia in the semi-circular canal might be related to a lower firing rate when applying this test. Based on our study method and timing of caloric test, we can confidently say that participants who score positive on the caloric test and are cured of BPPV do indeed have UVH. However, we need to be cautious about the two participants who persisted with BPPV at T2 and had abnormal scores on the caloric irrigation test as well.

The division of the participants occurred at the moment of the caloric irrigation test. The amount of time between the first consultation and the caloric irrigation test was approximately one month. First, we must be aware of the fact that during this time frame, one can develop an underlying vestibular disorder. As mentioned above, presence of BPPV can cause canal paresis on the ipsilateral side. Therefore, a participant could be categorized into the wrong group due to the large amount of time between the two test moments. In contrast, taking all these previously mentioned facts into account, we can conclude that the one-month waiting time is justified because having BPPV at the moment of the caloric test can possibly alter the test results, which could again lead to incorrect categorization. The research by Palmeri and Kumar (2024) suggests that the time to resolve BPPV is 4 to 6 weeks. This also clarifies the one-month waiting period.

Contrary to our expectations, the OABPPV+ did not score worse on the outcome of falls. Although the calculated odds ratio for fall history is 1.33, indicating that OABPPV+ had a 1.33 times higher chance of falling in their history, the 95% confidence interval for the odds ratio ranges from 0.28 to 6.32. Since the confidence interval includes 1, the odds ratio is not statistically significant. However, the wide confidence interval could be attributed to the small sample size of the study. Nevertheless, this result corresponds to the p-value of fall history ($p = 0.51$), which also showed no significant difference.

This study was executed consistently by the same researcher. Conversely, there were inconsistencies observed including complications with the caloric test due to unreliable measurements. Six participants were therefore excluded. Another matter was the absence of the participants caused by sickness, disturbing the consistency of the test and/or treatment sessions. Some sessions had to be rescheduled. Furthermore, the loss of one frailty questionnaire contributed to missing data for the subsets of exhaustion, weakness and physical inactivity. This prevented the classification of this participant conform to the phenotype of fried.

The strengths of the study involve the minimization of bias due to the fact that participants were not allocated into their groups until after the caloric irrigation test was performed. As a result, the blinded researcher could not exhibit any favoritism. The questionnaires distributed during the first contact moment (T0) were carefully controlled by the researcher at T1 to ensure that each item was accurately completed, potentially minimizing response bias (social desirability bias, acquiescence bias). Moreover, the proportion of women (n=19) is higher than that of men (n=12). Given that BPPV predominantly affects women, this demographic distribution enables us to draw a more generalized conclusion regarding the findings of the study (You et al., 2019). There is a clear temporal relationship established in the method which is crucial for inferring causality. Nonetheless, the vulnerabilities of the study encompass a small sample size, within a total of 31 participants. The proportion of the participants into the groups was not equally divided. This might have an influence on the results due to different sample sizes complicating drawing a general conclusion. Due to the fact that our investigation is a subset of a primary research, no power analysis was made. Therefore, it is not possible to determine the exact minimal number of participants needed for this secondary research. Consequently, conclusions of the obtained results must be interpreted with caution. After signing the informed consent, recruited participants had to wait approximately one week before receiving the first treatment. Consequently, they had to endure their symptoms for a longer period. This time frame might have made individuals less inclined to participate in the study.

In conclusion, the previously posited hypothesis, suggesting that OABPPV+ would exhibit poorer performances across all outcome measures, can be refuted based on our findings. However, individuals with an extra underlying vestibular disorder persist with more impairments on postural control than individuals with pure BPPV. To draw a clear conclusion, it is necessary to analyze the greater picture of the primary research and possibly other future studies about this topic. Clinicians have to be aware of the possibility that BPPV can occur with an extra underlying vestibular disorder. For this reason, the treatment plan has to be modified to encompass the entire patient to achieve better outcomes.

References

Andrews, A. W., Vallabhajosula, S., Boise, S., & Bohannon, R. W. (2023). Normal gait speed varies by age and sex but not by geographical region: a systematic review. *J Physiother*, *69*(1), 47-52. https://doi.org/10.1016/j.jphys.2022.11.005

Angner, E. (2010). Subjective well-being. *The Journal of Socio-Economics*, *39*(3), 361-368. https://doi.org/10.1016/j.socec.2009.12.001

Avila-Funes, J. A., Helmer, C., Amieva, H., Barberger-Gateau, P., Le Goff, M., Ritchie, K., Portet, F., Carriere, I., Tavernier, B., Gutierrez-Robledo, L. M., & Dartigues, J. F. (2008). Frailty among community-dwelling elderly people in France: the three-city study. *J Gerontol A Biol Sci Med Sci*, *63*(10), 1089-1096. https://doi.org/10.1093/gerona/63.10.1089

Bhattacharyya, N., Gubbels, S. P., Schwartz, S. R., Edlow, J. A., El-Kashlan, H., Fife, T., Holmberg, J. M., Mahoney, K., Hollingsworth, D. B., Roberts, R., Seidman, M. D., Steiner, R. W., Do, B. T., Voelker, C. C., Waguespack, R. W., & Corrigan, M. D. (2017). Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update). *Otolaryngol Head Neck Surg*, *156*(3_suppl), S1-S47. https://doi.org/10.1177/0194599816689667

Chen, S. Y., Feng, Z., & Yi, X. (2017). A general introduction to adjustment for multiple comparisons. *J Thorac Dis*, *9*(6), 1725-1729. https://doi.org/10.21037/jtd.2017.05.34

Cohen, H. S. (2004). Side-lying as an alternative to the Dix-Hallpike test of the posterior canal. *Otol Neurotol*, *25*(2), 130-134. https://doi.org/10.1097/00129492-200403000-00008

de Souza, L. F., Canever, J. B., Moreira, B. S., Danielewicz, A. L., & de Avelar, N. C. P. (2022). Association Between Fear of Falling and Frailty in Community-Dwelling Older Adults: A Systematic Review. *Clin Interv Aging*, *17*, 129-140. https://doi.org/10.2147/CIA.S328423

Di Carlo, S., Bravini, E., Vercelli, S., Massazza, G., & Ferriero, G. (2016). The Mini-BESTest: a review of psychometric properties. *Int J Rehabil Res*, *39*(2), 97-105. https://doi.org/10.1097/MRR.0000000000000153

Donovan, J., De Silva, L., Cox, H., Palmer, G., & Semciw, A. I. (2023). Vestibular dysfunction in people who fall: A systematic review and meta-analysis of prevalence and associated factors. *Clin Rehabil*, *37*(9), 1229-1247. https://doi.org/10.1177/02692155231162423

Edwards, C., & Franklin, E. (2024). Vestibular Rehabilitation. In *StatPearls*. https://www.ncbi.nlm.nih.gov/pubmed/34283519

Eysel-Gosepath, K., McCrum, C., Epro, G., Bruggemann, G. P., & Karamanidis, K. (2016). Visual and proprioceptive contributions to postural control of upright stance in unilateral vestibulopathy. *Somatosens Mot Res*, *33*(2), 72-78. https://doi.org/10.1080/08990220.2016.1178635

Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., McBurnie, M. A., & Cardiovascular Health Study Collaborative Research, G. (2001). Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*, *56*(3), M146-156. https://doi.org/10.1093/gerona/56.3.m146

Gomez, F., Curcio, C. L., & Duque, G. (2011). Dizziness as a geriatric condition among rural community-dwelling older adults. *J Nutr Health Aging*, *15*(6), 490-497. https://doi.org/10.1007/s12603-011-0050-4

Hall, C. D., Herdman, S. J., Whitney, S. L., Anson, E. R., Carender, W. J., Hoppes, C. W., Cass, S. P., Christy, J. B., Cohen, H. S., Fife, T. D., Furman, J. M., Shepard, N. T., Clendaniel, R. A., Dishman, J. D., Goebel, J. A., Meldrum, D., Ryan, C., Wallace, R. L., & Woodward, N. J. (2022). Vestibular Rehabilitation for Peripheral Vestibular Hypofunction: An Updated Clinical Practice Guideline From the Academy of Neurologic Physical Therapy of the American Physical Therapy Association. *J Neurol Phys Ther*, *46*(2), 118-177. https://doi.org/10.1097/NPT.0000000000000382

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. https://doi.org/10.2522/ptj.20080071

Iwasaki, S., & Yamasoba, T. (2015). Dizziness and Imbalance in the Elderly: Age-related Decline in the Vestibular System. *Aging Dis*, *6*(1), 38-47. https://doi.org/10.14336/AD.2014.0128

Jacobson, G. P., & Newman, C. W. (1990). The development of the Dizziness Handicap Inventory. *Arch Otolaryngol Head Neck Surg*, *116*(4), 424-427. https://doi.org/10.1001/archotol.1990.01870040046011

Kabaya, K., Katsumi, S., Fukushima, A., Esaki, S., Minakata, T., & Iwasaki, S. (2023). Assessment of semicircular canal function in benign paroxysmal positional vertigo using the video head impulse test and caloric test. *Laryngoscope Investig Otolaryngol*, *8*(2), 525-531. https://doi.org/10.1002/lio2.1020

Kim, H. A., Park, S. W., Kim, J., Kang, B. G., Lee, J., Han, B. I., Seok, J. I., Chung, E. J., Kim, J., & Lee, H. (2017). Efficacy of mastoid oscillation and the Gufoni maneuver for treating apogeotropic horizontal benign positional vertigo: a randomized controlled study. *J Neurol*, *264*(5), 848-855. https://doi.org/10.1007/s00415-017-8422-2

Kim, J. S., & Zee, D. S. (2014). Clinical practice. Benign paroxysmal positional vertigo. *N Engl J Med*, *370*(12), 1138-1147. https://doi.org/10.1056/NEJMcp1309481

Korres, S. G., Balatsouras, D. G., & Ferekidis, E. (2004). Electronystagmographic findings in benign paroxysmal positional vertigo. *Ann Otol Rhinol Laryngol*, *113*(4), 313-318. https://doi.org/10.1177/000348940411300411

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. https://doi.org/10.1111/jgs.17485

Mancini, M., Horak, F. B., & Nutt, J. G. (2020). *Balance dysfunction in Parkinson's disease : basic mechanisms to clinical management*. Elsevier/Academic Press.

Mandala, M., Salerni, L., & Nuti, D. (2019). Benign Positional Paroxysmal Vertigo Treatment: a Practical Update. *Curr Treat Options Neurol*, *21*(12), 66. https://doi.org/10.1007/s11940-019-0606-x

McDonnell, M. N., & Hillier, S. L. (2015). Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. *Cochrane Database Syst Rev*, *1*, CD005397. https://doi.org/10.1002/14651858.CD005397.pub4

McKay, M. A., Mensinger, J. L., & Whitehouse, C. R. (2022). The Relationship of Fear of Falling and Quality of Life: The Mediating Effects of Frailty and Depression. *J Community Health Nurs*, *39*(4), 251-261. https://doi.org/10.1080/07370016.2022.2073792

Moraes, D. C., Lenardt, M. H., Seima, M. D., Mello, B. H., Setoguchi, L. S., & Setlik, C. M. (2019). Postural instability and the condition of physical frailty in the elderly. *Rev Lat Am Enfermagem*, *27*, e3146. https://doi.org/10.1590/1518-8345.2655-3146 (Instabilidade postural e a condicao de fragilidade fisica em idosos.)

Morgan, M. T., Friscia, L. A., Whitney, S. L., Furman, J. M., & Sparto, P. J. (2013). Reliability and validity of the Falls Efficacy Scale-International (FES-I) in individuals with dizziness and imbalance. *Otol Neurotol*, *34*(6), 1104-1108. https://doi.org/10.1097/MAO.0b013e318281df5d

Nasruddin, H., Justine, M., & Manaf, H. . (2022). Gait and Postural Control Characteristics among Individuals with Benign Paroxysmal Positional Vertigo: A Scoping Review. *Malaysian Journal of Medicine and Health Sciences 18*, 377-386, Article 50. https://doi.org/10.47836/mjmhs18.s15.50

O'Sullivan, S. B., Schmitz, T. J., & Fulk, G. D. (2019). *Physical rehabilitation* (Seventh edition. ed.). F.A. Davis Company,.

Olivecrona, E., Zborayova, K., Barrenas, M. L., & Salzer, J. (2022). Comparison Between the Video Head Impulse Test and Caloric Irrigation During Acute Vertigo. *Indian J Otolaryngol Head Neck Surg*, *74*(Suppl 3), 4475-4482. https://doi.org/10.1007/s12070-022-03123-z

Osoba, M. Y., Rao, A. K., Agrawal, S. K., & Lalwani, A. K. (2019). Balance and gait in the elderly: A contemporary review. *Laryngoscope Investig Otolaryngol*, *4*(1), 143-153. https://doi.org/10.1002/lio2.252

Palmeri, R., & Kumar, A. (2024). Benign Paroxysmal Positional Vertigo. In *StatPearls*. https://www.ncbi.nlm.nih.gov/pubmed/29261987

Pauwels, S., Casters, L., Lemkens, N., Lemmens, W., Meijer, K., Meyns, P., van de Berg, R., & Spildooren, J. (2023). Gait and Falls in Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis. *J Neurol Phys Ther*, *47*(3), 127-138. https://doi.org/10.1097/NPT.0000000000000438

Peters, D. M., Fritz, S. L., & Krotish, D. E. (2013). Assessing the reliability and validity of a shorter walk test compared with the 10-Meter Walk Test for measurements of gait speed in healthy, older adults. *J Geriatr Phys Ther*, *36*(1), 24-30. https://doi.org/10.1519/JPT.0b013e318248e20d

Pollak, L., Davies, R. A., & Luxon, L. L. (2002). Effectiveness of the particle repositioning maneuver in benign paroxysmal positional vertigo with and without additional vestibular pathology. *Otol Neurotol*, *23*(1), 79-83. https://doi.org/10.1097/00129492-200201000-00018

Saito, Y., Nakamura, S., Tanaka, A., Watanabe, R., Narimatsu, H., & Chung, U. I. (2022). Evaluation of the validity and reliability of the 10-meter walk test using a smartphone application among Japanese older adults. *Front Sports Act Living*, *4*, 904924. https://doi.org/10.3389/fspor.2022.904924

Salari, N., Darvishi, N., Ahmadipanah, M., Shohaimi, S., & Mohammadi, M. (2022). Global prevalence of falls in the older adults: a comprehensive systematic review and meta-analysis. *J Orthop Surg Res*, *17*(1), 334. https://doi.org/10.1186/s13018-022-03222-1

Shepard, N. T., & Jacobson, G. P. (2016). The caloric irrigation test. *Handb Clin Neurol*, *137*, 119-131. https://doi.org/10.1016/B978-0-444-63437-5.00009-1

Shimada, H., Park, H., Makizako, H., Doi, T., Lee, S., & Suzuki, T. (2014). Depressive symptoms and cognitive performance in older adults. *J Psychiatr Res*, *57*, 149-156. https://doi.org/10.1016/j.jpsychires.2014.06.004

Soysal, P., Veronese, N., Thompson, T., Kahl, K. G., Fernandes, B. S., Prina, A. M., Solmi, M., Schofield, P., Koyanagi, A., Tseng, P. T., Lin, P. Y., Chu, C. S., Cosco, T. D., Cesari, M., Carvalho, A. F., & Stubbs, B. (2017). Relationship between depression and frailty in older adults: A systematic review and meta-analysis. *Ageing Res Rev*, *36*, 78-87. https://doi.org/10.1016/j.arr.2017.03.005

Sun, J., Ma, X., Yang, Y., He, K., Wang, W., Shen, J., Wang, L., Chen, X., Jin, Y., Yang, J., & Chen, J. (2023). Associations between cognition, anxiety, depression, and residual dizziness in elderly people with BPPV. *Front Aging Neurosci*, *15*, 1208661. https://doi.org/10.3389/fnagi.2023.1208661

Taguchi, C. K., Menezes, P. L., Melo, A. C. S., Santana, L. S., Conceicao, W. R. S., Souza, G. F., Araujo, B. C. L., & Silva, A. R. D. (2022). Frailty syndrome and risks for falling in the elderly community. *Codas*, *34*(6), e20210025. https://doi.org/10.1590/2317-1782/20212021025pt (Sindrome da fragilidade e riscos para quedas em idosos da comunidade.)

van Esch, B. F., Nobel-Hoff, G. E., van Benthem, P. P., van der Zaag-Loonen, H. J., & Bruintjes, T. D. (2016). Determining vestibular hypofunction: start with the video-head impulse test. *Eur Arch Otorhinolaryngol*, *273*(11), 3733-3739. https://doi.org/10.1007/s00405-016-4055-9

Vaz, D. P., Gazzola, J. M., Lanca, S. M., Dorigueto, R. S., & Kasse, C. A. (2013). Clinical and functional aspects of body balance in elderly subjects with benign paroxysmal positional vertigo. *Braz J Otorhinolaryngol*, *79*(2), 150-157. https://doi.org/10.5935/1808-8694.20130027

Vereeck, L., Truijen, S., Wuyts, F., & Van de Heyning, P. H. (2006). Test-retest reliability of the Dutch version of the Dizziness Handicap Inventory. *B-ENT*, *2*(2), 75-80. https://www.ncbi.nlm.nih.gov/pubmed/16910291

Viveiro, L. A. P., Gomes, G. C. V., Bacha, J. M. R., Carvas Junior, N., Kallas, M. E., Reis, M., Jacob Filho, W., & Pompeu, J. E. (2019). Reliability, Validity, and Ability to Identity Fall Status of the Berg Balance Scale, Balance Evaluation Systems Test (BESTest), Mini-BESTest, and Brief-BESTest in Older Adults Who Live in Nursing Homes. *J Geriatr Phys Ther*, *42*(4), E45-E54. https://doi.org/10.1519/JPT.0000000000000215

Wexler, D. B. (1994). Nonlinearity of the Jongkees difference equation for vestibular hypofunction. *Otolaryngol Head Neck Surg*, *111*(4), 485-487. https://doi.org/10.1177/019459989411100416

Xue, Q. L. (2011). The frailty syndrome: definition and natural history. *Clin Geriatr Med*, *27*(1), 1-15. https://doi.org/10.1016/j.cger.2010.08.009

Yetiser, S., & Ince, D. (2017). Caloric Analysis of Patients with Benign Paroxysmal Positional Vertigo. *J Int Adv Otol*, *13*(3), 390-393. https://doi.org/10.5152/iao.2017.3312

You, P., Instrum, R., & Parnes, L. (2019). Benign paroxysmal positional vertigo. *Laryngoscope Investig Otolaryngol*, *4*(1), 116-123. https://doi.org/10.1002/lio2.230

Zhang, Y., Wang, H., Yao, Y., Liu, J., Sun, X., & Gu, D. (2021). Walking stability in patients with benign paroxysmal positional vertigo: an objective assessment using wearable accelerometers and machine learning. *J Neuroeng Rehabil*, *18*(1), 56. https://doi.org/10.1186/s12984-021-00854-y

Zhu, R. T., Van Rompaey, V., Ward, B. K., Van de Berg, R., Van de Heyning, P., & Sharon, J. D. (2019). The Interrelations Between Different Causes of Dizziness: A Conceptual Framework for Understanding Vestibular Disorders. *Ann Otol Rhinol Laryngol*, *128*(9), 869-878. https://doi.org/10.1177/0003489419845014

Appendix

Table 1

Demographic Characteristic

Variable	OABPPV (n=21)	OABPPV+ (n=10)	p value
Age			0.95[a]
Mean±SD	72.62±4.85	72.50±4.50	
Range	64-82	65-79	
Sex			**0.05[b]**
Male	11 (52,4%)	1 (10%)	
Female	10 (47,6%)	9 (90%)	
Weight			0.88[a]
Mean±SD	75.99±11.12	75.35±11.45	
Range	58-102	58-94	
Height			0.54[a]
Mean±SD	1.66±0.092	1.64±0.062	
Range	1.46-1.82	1.56-1.76	
Walking aid (n)			0.08[b]
Four-wheel rollator	0	1(10%)	
Stick/crutch	1(5%)	2(20%)	
None	20(95%)	7(70%)	
Sleeping pattern (n)			0.53[b]
Long time to sleep	1(5%)	1(10%)	
Restless sleeper	7(33%)	1(10%)	
Long time to sleep + Restless sleeper	2(10%)	1(10%)	
Good	11(52%)	7(70%)	
Number of medications			0.19[a]
Mean±SD	4.33±2.73	5.70±0.83	
Range	0-10	2-10	
MOCA			0.60[a]
Mean±SD	24.00±3.45	23.20±4.849	
Range	14-30	16-29	
BPPV (n)			0.30[b]
RPSCC	9(43%)	4(40%)	
LPSCC	9(43%)	4(40%)	
RLSCC GEO	0	1(10%)	
RLSCC AGEO	3(14%)	0	
LLSCC GEO	0	1(10%)	
LLSCC AGEO	0	0	
Symptom duration (n)			0.25[b]
Some days	3(14%)	0	
Some weeks	2(10%)	3(30%)	
Several months	16(76%)	7(70%)	

Note. n number of participants, % percentage, mean± standard deviation for normal distributed data, [a] independent t-test, [b] fisher's exact test, RPSCC right posterior semi-circular canal, LPSCC left posterior semi-circular canal, GEO geotroop, AGEO ageotroop, LLSCC left lateral semi-circular canal, RLSCC right lateral semi-circular canal.

Table 2:

Holm-Bonferrroni Correction For Multiple Hypothesis Tests Of The Outcome Variables.

Outcomes	**OABPPV (n=21)**	**OABPPV+ (n=10)**	**p-values**	**Corrected α**
Balance, mean ± SD				
Mini-BESTest_TOT	22.81±3.56	19.10±5.33	0.02[a]	0.01
Mini-BESTest_ANTICI	4.57±1.25	3.50±1.43	0.02[c]	0.01
Mini-BESTest_ SO	5.76±0.54	4.50±1.27	**<.001**[c]	0.01
Mini-BESTest_GAIT	8.19±1.40	6.80±2.25	0.05[c]	0.02
Mini-BESTest_REAC	4.29±1.59	4.30±2.16	0.40[c]	0.05
10 meter walk test (m/s)	1±0.19	0.88±0.18	0.05[a]	0.03
Number of treatments, mean ± SD	2.10±1.3	2±1.49	0.36[c]	0.05
Sense of well-being, mean ± SD				
DHI_TOT	34.67±17.63	33.60±14.66	0.57[a]	0.05
DHI_F	13.05±8.48	13.20±7.44	0.48[a]	0.03
DHI_P	14.29±5.15	14.60±3.27	0.43[a]	0.01
DHI_E	7.33±5.94	5.80±5.12	0.21[c]	0.01
FES-I	27.19±10.29	28.20±11.34	0.42[c]	0.01
GDS-15	3.14±3.26	2.60±1.90	0.47[c]	0.02
Frailty, n (%)				
Unintentional weight loss	5 (23.8)	1 (10)	0.35[b]	0.01
Exhaustion	10 (47.6)	6 (60)	0.82[b]	0.03
Slowness	6 (28.6)	5 (50)	0.94[b]	0.05
Weakness	7 (33.3)	3 (30)	0.56[b]	0.01
Physical inactivity	16 (76.2)	8 (80)	0.69[b]	0.02
Frailty category			0.70[b]	0.02
Robust	5(25)	3(30)		
Prefrail	9(45)	3(30)		
Frail	6(30)	4(40)		
Falls, n (%)			0.51[b]	0.03
Fall history	7/14 (33.3)	4/6 (40)		
Yes/No	OR:1,333	95% CI [0.28,6.32]		
Amount of falls			0.41[c]	0.02
0	14 (66.6)	6 (60)		
1	3 (14.3)	2 (20)		
2	3 (14.3)	2 (20)		
>2	1 (4.8)	0		
Reason of falls			0.85[b]	0.05
Accidental	4(19)	3 (30)		
Dizziness	3 (14.3)	1 (10)		
BPPV at T2, n (%)	5 (23.8)	2 (20)	0.60[b]	0.05

Note. TOT total, ANTICI anticipatory, SO sensory orientation, GAIT dynamic gait, REAC reactive postural control, DHI dizziness handicap inventory, F functional, P physical, E emotional, FES-I falls efficacy scale international, GDS geriatric depression scale, [a] independent t-test, [b] fisher's exact test, [c] Wilcoxon rank sum test, n number of participants