JGG 2023;71:166-174
doi: 10.36150/2499-6564-N620

Posturographic study in older patients with instability associated with benign paroxysmal positional vertigo: a prospective analysis

Paula Peña Navarro[1], Sofía Pacheco López[1], Susana Marcos Alonso[1], Cristina Nicole Almeida Ayerve[1], Ana Belén Alonso San Eloy[1], Juan Carlos Del Pozo De Dios[1], Hortensia Sánchez Gómez[1], Santiago Santa Cruz Ruiz[1,2], Ángel Batuecas Caletrío[1,2]

[1] Neurotology Unit, ENT Department, University Hospital of Salamanca, IBSAL, Salamanca, Spain;[2] ENT Department, Faculty of Medicine, University of Salamanca, Salamanca, Spain

Background and aims. Benign paroxysmal positional vertigo is the most frequent type of peripheral vertigo. The characteristic vertiginous symptoms with head movements are not always present but can often be described as persistent instability lasting weeks or months. It is more common in elderly patients, significantly restricting their ability to perform everyday activities. We aimed to assess the factors related to a greater propensity to present such instability. Methods. A prospective observational study was conducted on a cohort of 50 patients with benign paroxysmal positional vertigo. The study comprised two groups: older and younger than 70 years. Questionnaires for dizziness (Dizziness Handicap Inventory) and risk of falls (falls efficacy scale) were administered to both groups, and a dynamic posturography was conducted upon diagnosis of benign paroxysmal positional vertigo and once resolved. Results. In the younger group, the mean age was 51.5 years (56.7% women). Regarding the subjective assessment, both questionnaires improved significantly ($p < 0.001$). The objective values assessed by posturographic analysis improved significantly after the treatment. Conversely, the elderly group was aged 77.4 years on average (68.8% women). In the subjective assessment, only falls efficacy scale improved ($p = 0.015$), and the posturographic values improved marginally than that in the younger group, with no significant improvement.
Conclusions. The study using dynamic posturography could play a role in the assessment of residual dizziness and will allow the implementation of a targeted treatment for patients.

Key words: benign paroxysmal positional vertigo, instability, dynamic posturography

Received: March 30, 2023
Published: July 20, 2023

Correspondence
Sofía Pacheco López
Neurotology Unit, ENT Department, University Hospital of Salamanca, IBSAL, P.º de San Vicente 182, 37007 Salamanca. Spain
Tel. +34 923 29 11 00
E-mail: spacheco.1@hotmail.com

How to cite this article: Peña Navarro P, Pacheco López S, Marcos Alonso S, et al. Posturographic study in older patients with instability associated with benign paroxysmal positional vertigo: a prospective analysis. Journal of Gerontology and Geriatrics 2023;71:166-174. https://doi.org/10.36150/2499-6564-N620

INTRODUCTION

Europe has the oldest population in the world, with 19% of its citizens aged above 65 years in 2021. Of the global population, 10% are above 65 years, and the figures are estimated to reach 1.5 billion by 2050, representing approximately 22% of the total population. In this context, the well-being of our elderly is essential; that is, to ensure an autonomous and

independent lifestyle for their daily activities. Owing to aging, along with the other systems in the body, deterioration of the vestibular system occurs that can cause multiple otoneurological symptoms such as vertigo, instability, gait disturbances, and even occasional falls derived from the previous symptoms [1]. Falls are one of the main causes of lesions, disability, institutionalisation, and even death among elderly individuals. They are considered markers for frailty and are the most characteristic example of geriatric symptoms [2].

Postural control is a complex motor ability that allows controlling the centre of mass of the body with regard to a base of support through the interaction between the musculoskeletal and neural systems. It is essential in adaptive and anticipatory movements to avoid falls. It involves controlling the body position in space with two goals: orientation and stability. To ensure that postural balance is maintained in space, the three systems; vestibular, visual, and somatosensory must be combined, and they are coordinated by the central nervous system to maintain the balance and ensure the necessary adjustments in each situation [1].

Benign paroxysmal positional vertigo (BPPV) is the most common peripheral vestibular disorder. It appears in approximately 25% of all vertigo cases with a vestibular origin [3-6] and has a prevalence of 2.4% in the general population [3,7,8]. It is particularly relevant among the elderly because the age of onset of symptoms is generally between 60 and 70 years, and the risk of developing increases with age until it reaches a prevalence of 10% among individuals > 80 years [9]. The symptoms of vertigo are the most common cause of medical consultation in patients aged > 75 years. It has a higher prevalence among women, with a ratio of 2:1 [10] and a greater incidence in the posterior semicircular canal. The etiology is generally unknown, followed by cranioencephalic trauma, migraine, or Meniere's disease [10,11]. BPPV is caused by the mechanical stimulation of the vestibular receptors owing to the dislodgement or abnormal displacement of the otoconia in the utriculum through the semicircular canals, which causes the characteristic symptoms of dizziness and spinning sensation [12] that can last for seconds and are triggered by certain head movements. However, BPPV is relatively frequently described clinically as insidious instability, with approximately 40% of patients aged > 70 years diagnosed upon presenting symptoms of instability [9,13]. Additionally, some patients report residual dizziness after the resolution of BPPV, with variable duration, which can critically limit their quality of life. These symptoms of unbalance can cause depression among the elderly, leading to reduced daily activities [13] and a risk factor for falls, which in turn is a significant cause of disability, hospital admission, and even lesion-related deaths in patients aged > 75 years [14].

In contrast, Computerised Dynamic Posturography (CDP) is a tool that registers different alterations in balance and differentiates between the contributions from each sensory system to postural control. It also assesses the skill of the balance system to adapt to different conditions in which it must select between different sensory alternatives or strategies to maintain stability. Two different tests are performed: Limits of Stability Testing (LoS) and Sensory Organisation Test (SOT). The LoS quantifies the patient's ability to displace their centre of gravity to different positions in space, which makes it possible to analyse their postural control while moving or during a dynamic displacement of their centre of gravity. In contrast, the SOT analyses the relative contribution of somatosensory, visual, and vestibular receptors to the global stability of the patient. Moreover, it shows which of the systems involved in maintaining the balance are responsible for the patient's stability and their capacity to maintain their balance with erroneous and/or reduced sensory inputs [15].

Although it is benign, BPPV may have significant consequences, which can be highly incapacitating and even compromise the capacity to perform basic activities of daily life. These consequences appear mainly during the acute moments of vertigo; however, they may have some implications between crises with functional and emotional consequences. Thus, the knowledge of the characteristics of global balance in elderly patients with BPPV must be enhanced and variables that may be associated with balance loss and postural control must be identified to implement targeted prevention and rehabilitation strategies [1,16,17]. Currently, limited literature analyses the functional aspects and quality of life of the elderly population after BPPV treatment, specifically focusing on their postural control.

We hypothesised that these symptoms of instability associated with BPPV appear more frequently in elderly patients than those in younger patients and have a significant impact on their quality of life. Therefore, the risk of falls is increased, with the corresponding socioeconomic impact. Collectively, our research group is motivated by the importance of identifying and applying an early treatment for BPPV in the elderly population, which can improve their quality of life and prevent falls. Therefore, this study aimed to research the clinical and posturographic factors related to a higher probability to present this instability and to determine whether age is a determining factor in this process.

METHODS

Design

An observational, prospective study was conducted with a cohort of 50 patients with a final diagnosis of

BPPV established with manoeuvres to provoke nystagmus (Dix-Hallpike, McClure-Pagnini, and cephalic hyperextension). This cohort was assessed by the External Consultation Unit or as an emergency between the years 2020 and 2022 by the Department of Otorhinolaryngology of the University Healthcare Complex of Salamanca.

Population

The inclusion criteria were as follows: voluntary patients aged > 18 years, with a stable medical condition, without a prior history of other concomitant vestibular conditions, without episodes of BPPV in the previous year, and without previous treatment of vestibular rehabilitation. The sample was divided into 30 patients aged < 70 years or the "younger population" (cohort A) and 16 patients aged > 70 years or the "older population" (cohort B).

All the patients signed an informed consent form before being included in the study. This study follows the Ethical principles for medical research involving human participants presented in the 2013 Declaration of Helsinki [18]. It also received approval from the Institutional Review Board (CEIM) of the University Healthcare Complex of Salamanca.

VARIABLES

Upon inclusion of each patient in the study and after signing the informed consent form, the diagnosis of BPPV was obtained and we collected the demographic and clinical data that could be related to BPPV (this data collection point was classified as taking place before the study). The data included patients' personal medical history (cranioencephalic trauma, prolonged bed rest, cardiovascular risk factors, history of migraine, hearing, oncological or neurological disorders, vitamin D deficiency, or thyroid disorders), risk factors that may have contributed to the symptoms (sleeping position, previous neck, cardiovascular, traumatological or visual disorders, a history of BPPV from more than one year ago, walking aids, and use of antivertigo drugs), and the characteristics of the BPPV, both during anamnesis and in the otoneurological examination, including the characteristics of the nystagmus (time of evolution of symptoms, affected semicircular canal, affected side, latency and duration of the nystagmus, and therapeutic approach). The patients also completed questionnaires on instability (Dizziness Handicap Inventory: DHI) and the risk of falls (Falls Efficacy Scale: FES) and underwent CDP that included the analysis of stability limits and a sensory organisation test. Following this, the particle repositioning manoeuvre was performed, and the patient was reassessed after 10 days. The follow-up period continued until the symptoms were resolved, as assessed by the same diagnostic manoeuvrers and with the same treatment if the symptoms persisted. In the case of resolution of BPPV (or with lack of resolution after five therapeutic manoeuvres), data regarding patients' symptoms were collected again (and this was classified as taking place after the study). The patients completed the DHI and FES questionnaires again, and a second CDP was performed.

Statistical analysis

After the data collection, a descriptive analysis was conducted for clinical and posturographic variables. Subsequently, a comparative statistical analysis was performed using contingency tables. This was initially an intragroup study with statistical analysis in each cohort for the results obtained during the acute symptoms and after they were resolved, with McNemar's, and Wilcoxon's tests for paired data. An intergroup analysis was also performed to compare the results of both cohorts before and after treatment using the Fisher and the Mann-Whitney U tests. The software IBM SPSS Statistics version 20 was used to perform statistical analysis, and values of $p < 0.05$ were considered significant.

RESULTS

We had a total sample of 46 patients after four patients were excluded from the study for not completing the follow-up. The sample was divided into two groups: cohort A, with 30 patients < 70 years of age and Cohort B, with 16 patients > 70 years of age.

In cohort A, the average age was 51.50 years and 56.7% of the population were women. In cohort B, the average age was 77.38 years and 68.8% of the population were women. The differences regarding sex in both groups were not statistically significant ($p = 0.424$).

No statistically significant differences were observed between both groups regarding their personal history of risk factors for BPPV, such as cranioencephalic trauma ($p = 0.708$) or prolonged bed rest ($p = 0.318$). With regard to their medical history, both groups showed the same basal characteristics for cervical, neurological, cardiovascular, traumatological, or visual disorders (Tab. I).

In both groups, the most commonly affected semicircular canal was the posterior right canal, which was the side on which patients most commonly slept. With regard to the BPPV symptoms during the acute stage, the time of evolution of the symptoms (time from the onset of symptoms until medical consultation and

Table I. Demographic and clinical variables related to BPPV in both age groups and p value for statistical significance of their comparison.

	Cohort A < 70 YEARS (n = 30)	Cohort B ≥ 70 YEARS (n = 16)	P-value
Age (mean +/- standard deviation)	**51.5** +/-12.93	**77.38**+/-3.897	
Sex (M:F)	13:17 (**M = 56.7%**)	5:11 (**M = 68.8%**)	0.424
Cranioencephalic trauma	5 (**16.7%**)	2 (**12.5%**)	1
Prolonged bed rest	5 (**16.7%**)	1 (**6.3%**)	0.649
Cardiovascular risk factors	10 (**33.3%**)	10 (**62.5%**)	0.07
Migraine	9 (**30%**)	4 (**25%**)	1
Other risk factors			
Hearing disorder (sudden loss, surgery, ect.)	3 (**10%**)	1 (**6.3%**)	0.060
Cancer	1 (**3.3%**)	2 (**12.5%**)	
Neurological (previous stroke)	1 (**3.3%**)	2 (**12.5%**)	
Vitamin D deficiency/osteoporosis		2 (**12.5%**)	
Sleeping position			
Right	13 (**43.3%**)	9 (**56.3%**)	0.633
Left	7 (**23.3%**)	4 (**25%**)	
Indifferent	10 (**33.1%**)	3 (**18.8%**)	
Evolution of symptoms (days)	116.07 +/-344.27 (median **10**)	81.5 +/- 132.66 (median 30)	**0.017***
Previous disorders			
Cervical	16 (**53.3%**)	7 (**43.8%**)	0.758
Neurological	4 (**13.3%**)	16 (**100%**)	0.282
Cardiovascular	4 (**13.3%**)	3 (**18.8%**)	0.681
Traumatological	8 (**26.7%**)	3 (**18.8%**)	0.722
Visual	2 (**6.7%**)	4 (**25%**)	0.163
Previous BPPV (> 1 year before)	8 (**26.6%**)	6 (**37.6%**)	0.512
Walking aid	0	3 (**18.8%**)	**0.037***
Use of antivertigo drugs			
No	24 (**80%**)	10 (**62.5%**)	**0.023 ***
Sulpiride	4 (**13.3%**)	1 (**6.3%**)	
Diazepam	2 (**6.7%**)	3 (**18.8%**)	
Combination	0	2 (**12.5%**)	
Affected semicircular canal			
Posterior	25 (**83.3%**)	14 (**87.5%**)	0.702
Horizontal canalolithiasis	4 (**13.3%**)	1 (**6.3%**)	
Horizontal cupulolithiasis	1 (**3.3%**)	1 (**6.3%**)	
Superior	0	**0**	
Side			
Right	16 (**53.3%**)	6 (**37.5%**)	0.364
Left	14 (**46.7%**)	10 (**62.5%**)	
Latency	**2.27** +/- 1.48	**2.56** +/-2.34	0.99
Duration	**17.04** +-15.65	**14.87** +/-7.9	0.686
Manoeuvres			
Epley	25 (**83.3%**)	14 (**87.5%**)	1
Guffoni	5 (**16.7%**)	14 (**87.5%**)	
Jacovino	0		
Resolved*	29 (**96.7%**)	13 (**81.3%**)	0.114
Canal Change	2 (**6.7%**)	3 (**18.8%**)	0.325
No. of maneuvers performed 1 2 3 4 ≥ 5	 24 (**80%**) 5 (**16.7%**) 0 0 1 (**3.3%**)	 7 (**43.8%**) 3 (**18.8%**) 2 (**12.5%**) 1 (**6.3%**) 3 (**18.8%**)	**0.005***

***** It is considered as "resolved" when the manoeuvres are negative on examination or with lack of resolution after five therapeutic manoeuvres.

assessment by an ear, nose, throat [ENT] specialist) was significantly longer in Cohort B than in Cohort A (median differences: 10 days *vs* 30 days, p = 0.017). In this regard, older patients had significantly higher use of antivertigo drugs before treatment with BPPV than those in younger patients (p = 0.023). The number of manoeuvres required to resolve BPPV in the group of older patients was significantly higher than that in the younger patient group (p = 0.005). Approximately 18.8% of the patients in the group of older patients required five or more manoeuvres for the resolution, compared to only 3.3% in the group of younger patients (Tab. I).

With regard to the clinical variables reported subjectively by the patients and that included during anamnesis (Tab. II), in both groups, the characteristic positional vertigo symptoms improved significantly after treatment (p < 0.001), without significant differences between both groups. With regard to the instability symptoms subjectively reported by the patients, both groups improved significantly after treatment for BPPV. However, when comparing the degree of improvement between both groups, we observed that the improvement after treatment was significantly more noticeable in the group of younger patients than that in the older patient group (p = 0.048). The presence of positional symptoms compared to the instability before the treatment was not statistically significant in cohort A (p = 0.514), and it was close to being significant in cohort B (p = 0.065). The number of falls in both groups before and after treatment was reduced but was not significant in any of the groups, whereas the need for walking aids during their basal state was statistically significant (0% in cohort A *vs* 18.8% in cohort B, p = 0.014). With regard to the assessment through questionnaires, both the questionnaire for associated instability (DHI) and the risk of falls (FES) in cohort A showed a significant improvement (p < 0.001 in both of them), whereas only FES improved in cohort B (p = 0.015).

Tab. III describes the objective assessment of patients through CDP. Comparing the parameters with those of the LoS, we observed significant improvement after BPPV treatment in the group of patients < 70 years of age regarding the average reaction time in seconds (p = 0.003), movement speed (°/s) (p = 0.019), and maximum excursion (%) (p = 0.033). In contrast, the group of patients aged > 70 years of age did not show significant differences before and after the treatment with regard to their average reaction time (p = 0.099), movement speed (p = 0.053), endpoint excursion (%) (p = 0.078), maximum excursion (%) (p = 0.051), and directional control (%) (p = 0.266). Therefore, on comparing both groups, we observed a statistically significant difference for reaction time and movement speed after the resolution of BPPV (p = 0.000). Furthermore, a significant difference was also observed for endpoint excursion, maximum excursion and directional control during the acute stage of BPPV and after its resolution (p = 0.000).

Similar results were observed with the analysis of SOT. The parameters analysed revealed a greater improvement of BPPV-associated instability after treatment in the younger group than in the older group. This test assesses how patients use the somatosensory, visual, and vestibular information and provides significant results in its composite value (p < 0.001), somatosensory analysis (p = 0.038), and visual preference value (p < 0.001), which shows the patient's ability to assume

Table II. Subjective variables analyzed (symptoms reported by the patient and questionnaires) in each age group and p values for statistical significance of comparison between values before and after treatment and when comparing both groups. Being DHI dizziness handicap inventory and FES Falls Efficacy scale.

	Cohort A < 70 years			Cohort B ≥ 70 years			P-value (intergroup)	
	Before	After	P-value	Before	After	P-value	Before	After
Vertigo symptoms	28 (93.3%)	1 (3.3%)	< 0.001*	14 (87.5%)	0	< 0.001*	0.504	0.460
Instability symptoms	21 (70%)	8 (26.7%)	< 0.001*	14 (87.5%)	9 (56.3%)	0.031*	0.063	0.048*
No. of falls							0.502	1
0	25 (83.3%)	30 (100%)		12 (75%)	16 (100%			
≥ 1	5 (16.7%)	0	0.063	4 (25%)	0	0.125		
DHI	40.43 +/- 19.86	15.4+/-17.7	< 0.001*	35 +/-21.5	28.56+/- 29.7	0.277	0.304	0.286
FES	38.8 +/- 21.77	22.5 +/- 21.02	< 0.001*	40.56 +/- 17.4	26.44+/- 18.34	0.015*	0.782	0.258

Table III. Variables registered in the posturographic analysis of patients before and after treatment, and p values for statistical comparison in each age group (before and after treatment) and between both groups.

	Cohort A: < 70 Years			Cohort B: ≥ 70 Years			P-value (intergroup)	
	Pre	Post	P-value	Pre	Post	P-value	Pre	Post
Stability limits								
Reaction time (secs)	1.04	0.906	0.003*	7.39	1.21	0.099		0.000*
Movement speed (°/sec)	3.75	4.25	0.019*	8.74	3.3	0.053	0.264	0.006*
Endpoint excursion (%)	78.37	80.3	0.286	55.73	60.94	0.078	0.000*	0.000*
Maximum excursion (%)	90.6	93.4	0.033*	71.8	77.63	0.051	0.000*	0.000*
Directional control (%)	80	80.4	0.632	60.75	67.81	0.266	0.000	0.000
Sensory organization test								
Composite	74.3 +/-9.06	80.53+/-3.63	< 0.001*	58.63+/-17.15	67+/-13.38	0.004*	0.001*	< 0.001*
Somatosensorial	94.53+/-9.61	97.9+/-1.69	0.038 *	95.75+/-4.54	95.69+/-5.17	0.959	0.642	0.177
Visual	88.07+/-7.41	90.43+/-4.49	0.316	80.25+/-16.49	86.63+/-8.12	0.016*	0.008*	0.127
Vestibular	60.37+/-22.05	74.17+/-7.14	< 0.001*	32.94+/-32.28	48.06+/-28.14	0.064	0.013*	< 0.001*
Preference	103.0 +/-21.5	98.33+/-4.96	0.636	89.44 +/-27.89	93+/-14.46	0.796	0.212	0.278

erroneous visual information. The group of older patients showed differences before and after treatment for the composite value (p = 0.004) and in the management of visual information. Both in the acute stage of BPPV (the stage before treatment) and after the resolution of BPPV (the stage after treatment), there were differences between both groups. The group with older patients had a poorer basal status upon diagnosis, and after the vertigo episodes were resolved, they had more instability-related secondary effects than the group of patients under 70 years of age.

DISCUSSION

Instability and the consequent risk of falls in an elderly population with BPPV have been widely researched. In contrast, there are currently only initial and descriptive postulates on the posturographic repercussion of this condition, and only one publication [19] analysed stability limits in the acute stage of the symptoms and after they were resolved with Static Posturography instead of Dynamic, as in our case. This study also analysed the scores in the DHI questionnaire at those two points; however, our study also included the score from the FES questionnaire, which is more specific for the risk of falls, whose prevention is essential in the elderly population. Additionally, the preexisting study analysed 33 elderly patients and compared the results after the treatment with the same number of healthy patients, unlike our study, which compared the findings with a population of younger patients (under 70 years of age) in the aforementioned moments of the evolution of BPPV symptoms, which in our opinion provides greater reliability to the analysis, greater opportunities to compare it with other studies, and greater clinical impact. In addition, our study provides a more comprehensive and representative overview of this condition owing to the extent of data registered. In this regard, although several data did not show statistically significant differences between both groups, it is worth noting that the cardiovascular risk factors and comorbidities were close to being significant, at least clinically, in the population above 70 years of age with BPPV.

With regard to the characteristics of BPPV, we observed that in two cases with similar symptoms in the otoneurological examination (nystagmus with a median latency of 2 s and a median duration of 10 s in both cases), a different clinical impact associated with instability existed. Therefore, a longer median time of evolution, which is statistically significant was observed in the elderly population, as well as greater instability before the treatment, as reported by this population, which is close to being statistically significant. Therefore, both age groups showed a significant improvement in vertigo symptoms and instability after treatment, and the older population showed significantly greater instability after treatment, in line with previous studies. Consequently, a greater number of falls was observed in these older patients, which was not statistically significant but had a significant clinical impact, as reported by previously published studies on the repercussion of falls in terms of disability and quality of life. This fact was also confirmed by the DHI and FES questionnaires, in which patients over 70 years of age reported a lower degree of improvement after the resolution of BPPV, which can be due to greater residual dizziness associated with other causes of multifactorial instability. Additionally, and in

light of the results, a greater number of manoeuvres was required for the resolution of BPPV in the elderly population.

In contrast, the observed results revealed that it takes older patients a significantly longer time to be evaluated by an ENT specialist than younger patients. This can be because in this subpopulation of patients, instability is either not considered significant or is deemed as a typical age-related condition. In addition, based on these results, these elderly patients are more likely to be multi-medicated with anti-vertigo drugs than patients in cohort A, which may be explained by the longer time it takes them to be evaluated by an ENT specialist. This fact has multiple implications for the elderly population because polypharmacy in elderly patients is associated with an increase in adverse effects and interactions, loss of quality of life, and even greater mortality rates.

One hypothesis that could account for the physiopathology of balance problems after BPPV is the presence of scarce otoconial material in the affected semicircular canal after BPPV. Another possibility is that there could be a utricular dysfunction after the episode or even a residual sympathetic nervous system dysfunction [20].

Previous publications have shown worse scores in the posturographic limits of stability both in the healthy elderly population [21] and in that with instability. Although in this case the only statistically significant differences were found regarding the lower speed of movement of this population compared to the control group, which was also representative of the elderly population, without instability [22] and whose values were taken as a reference in our study. In light of the results of our study, we may conclude that the reaction time is similar in both groups and that this variable significantly improves in the younger group, while it remains stable in the older group despite the resolution of the symptoms, with values that are slightly higher than those of the healthy older population. In practical terms, we have observed that younger patients tend to resume their normal activities sooner after the resolution of BPPV after stimulation. Conversely, elderly patients still exhibit a longer reaction time despite the absence of symptoms. With regard to the movement speed, a clear improvement is observed for this parameter in cohort A after treatment, compared to similar values in cohort B before and after the treatment (in line with the reference values). The younger population may be more severely affected by the instability caused by BPPV in the acute stage, probably because they had not been exposed previously to permanent or multifactorial instability and are afraid of it, unlike the elderly population, who already had some degree of basal instability. Considering the endpoint and maximum excursions, the only statistically significant intragroup differences are found in the younger population with regard to the maximum excursions, although the observed significant differences between both groups for both parameters because the younger patients could cover a greater distance, highlighting the residual instability that patients aged > 70 years continue to experience even after receiving treatment. Finally, the younger population presents significantly greater directional control (they move in a straighter line toward their objective) than the elderly population. In the group of older patients, this control is lower than the reference values when they have BPPV, which is to be expected owing to the instability caused by this condition in patients over 70 years of age.

With regard to the Sensory Organisation Test, only few studies have analysed this aspect before and after treatment. One of the studies that focused on this topic was conducted by Wu et al. [23], who concluded that the defects in the dynamic balance function are a predictive factor for residual symptoms after successful treatment of BPPV but not during the acute stage of the symptoms. Another example is the study by Assal et al. [24], who also reported an important role of SOT analysis in residual dizziness after BPPV treatment. In our study, based on the results before and after treatment, we observed that all the parameters in the group of older patients showed less improvement than in the group of younger patients, and only the improvement of the average global balance and the management of visual information were statistically significant in the group of older patients. In contrast, it is necessary to take into account that the group of older patients presented worse global stability values than the group of younger patients (composite pre: $p < 0.001$). After the manoeuvres, the group with older patients still presented worse values for average global balance and management of vestibular information than the group with younger patients. Considering our current knowledge on this issue, these results cannot be explained from a physiopathological perspective, because BPPV episodes do not include a vestibular deficiency that may affect the levels of management of vestibular information. Further studies are required in this regard to clarify the reasons behind this finding.

The strengths of this study include the fact that, although there are previous references in the literature that discuss balance disorders after an episode of BPPV, there are few studies that focus on the posturographic analysis of these episodes before and after treatment. To date, this is the first study that focuses particularly on the risk of falls in the elderly population by analysing the results from the questionnaire created specifically for that goal (FES). Another strength is the significant amount of demographic and clinical parameters, which include previous conditions and risk factors

of the patients included in the study. The main limitation of this analysis is, apart from the number of patients included (n = 46), the fact that the follow-up period of our patients ends with the resolution of the BPPV episode, and there is no information regarding the parameters of the patients weeks or months after the episode was resolved. Another limitation of the present study is that the separation between the two groups (< 70 and > 70) is artificial, because there are no real differences in relation to age, for example, between a 69-year-old individual and a 71- year-old one. However, if patients of an age range (for example, between 60 and 70 years) had been excluded the sample of patients would have been even smaller. Another issue that would have been interesting is the assessment of the basal vestibular function of the patients, because it is possible that the group over 70 years, there is a basal vestibular deficit (related to an eventual presbyvestibulopathy) that could explain the worse posturographic results, both in terms of score and less improvement. Therefore, and owing to these promising results, we will continue to expand the population sample of both groups to give greater statistical consistency to the study. It would be interesting to conduct new randomised tests with a longer follow-up period that will allow us to draw conclusions regarding the long-term post-treatment instability experienced by elderly patients with vestibular disorders, to complement these findings with a third posturographic analysis several months after the resolution of the BPPV episode to assess the evolution of the residual dizziness among the elderly, and to study the possibility to recovery stability with a slower and more progressive pace in this population. This would give greater visibility to the relevance of BPPV and the instability it causes in this subpopulation of patients, and it would allow us to implement prevention and early treatment strategies for this highly prevalent condition.

CONCLUSIONS

BPPV can be associated with residual dizziness that can be highly limiting, particularly in the elderly population, because it involves a higher risk of falls and, consequently, higher morbidity and mortality rates for this group of patients. CDP testing plays an important role in the assessment of residual dizziness in this subpopulation of patients. The LoS test and the SOT can objectively reveal instability and the risk of falls that have already been observed in previous studies. Additionally, these results in CDP could assist in a targeted rehabilitation treatment to reduce the risk of falls and consequently improve the quality of life of this population.

Acknowledgements

We are grateful to all nurses who perform vestibular tests and the doctors who took part in this study. We specifically thank the Otoneurology Unit of the Salamanca University Assistance Complex and the Salamanca Biomedical Research Institute for helping us carry it out. We would also like to thank Editage (www.editage.com) for English language editing.

Conflict of interest statement

The Authors declare no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

ABC, SPL, PPN: contributed to the conception and design of the work; ABC, SPL, PPN, SMA, CNAA: contributed to the acquisition of data; ABAS: performed the posturografic analyses; SPL, PPN: performed the analyses; all authors contributed to the interpretation of data for the work; ABC, SPL, PPN: drafted the manuscript. All gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

Ethical consideration

The research was conducted ethically, with all procedures being performed in accordance with the World Medical Association's Declaration of Helsinki, and was approved by the Institutional Review Board (CEIM) of the University Healthcare Complex of Salamanca, Spain (protocol number PI2022061053, date of approval: 30 June 2022).

References

1 Silva C, Ribeiro K, Freitas R, et al. Vertiginous symptoms and objective measures of postural balance in elderly people with benign paroxysmal positional vertigo submitted to the Epley maneuver. Int Arch Otorhinolaryngol 2016;20:61-68. https://doi.org/10.1055/s-0035-1565915

2 Formiga F. Las caídas, un síndrome geriátrico por excelencia. Rev Esp Geriatr Gerontol 2009;44:299-300. https://doi.org/10.1016/j.regg.2009.07.008

3 Kozak HH, Dündar MA, Uca AU, et al. Anxiety, mood, and personality disorders in patients with benign paroxysmal positional vertigo. Noropsikiyatri Ars 2018;55:49-53. https://doi.org/10.5152/npa.2016.18143

4 Carnevale C, Arancibia-Tagle DJ, Rizzo-Riera E, et al. Efficacy of particle repositioning manoeuvres in benign positional paroxysmal vertigo: a revision of 176 cases treated in a tertiary care centre. Acta Otorrinolaringol Esp 2018;69:201-207. https://doi.org/10.1016/j.otoeng.2017.06.014

5 Chan KC, Tsai YT, Yao-Hsu Y, et al. Osteoporosis is associated with increased risk for benign paroxsymal vertigo: a nationwide population-based study. Arch Osteoporos 2017;1:106. https://doi.org/10.1007/s11657-017-0403-7

6 Chu CH, Liu CJ, Lin LY, et al. Migraine is associated with an increased risk for benign paroxysmal positional vertigo: a nationwide population-based study. J Headache Pain 2015;16:1-7. https://doi.org/10.1186/s10194-015-0547-z

7 Cetin YS, Ozmen OA, Demir UL, et al. Comparison of the effectiveness of brandt-daroff vestibular training and epley canalith repositioning maneuver in benign paroxysmal positional vertigo long term result: a randomized prospective clinical trial. Pakistan J Med Sci 2018;34: 558-563. https://doi.org/10.12669/pjms.343.14786

8 Von Brevern M, Radtke A, Lezius F, et al. Epidemiology of benign paroxysmal positional vertigo: a population-based study. J Neurol Neurosurg Psychiatry 2007;78:710-715. https://doi.org/10.1136/jnnp.2006.100420

9 Batuecas-Caletrio A, Trinidad-Ruiz G, Zschaeck C, et al. Benign paroxysmal positional vertigo in the elderly. Gerontology 2013;59:408-412. https://doi.org/10.1159/000351204

10 Ramos Y P, Waissbluth AS, Correa FD, et al. Vértigo posicional paroxístico benigno: factores de riesgo asociados y eficacia de las maniobras de reposición. Rev Otorrinolaringol Cir Cabeza Cuello 2020;80:19-27. http://dx.doi.org/10.4067/S0718-48162020000100019

11 Silva C, Amorim AM, Paiva A. Benign paroxysmal positional vertigo – a review of 101 cases. Acta Otorrinolaringol Esp 2015;66:205-209. https://doi.org/10.1016/j.otorri.2014.09.003

12 Nuti D, S. Zee D. Positional vertigo and benign paroxysmal positional vertigo. M. Bronstein A, ed. by. Oxford Testbook of Vertigo and Imbalance. 1.ª ed. Oxford: Oxford University Press 2013, pp. 217-230.

13 Balatsouras D, Koukoutsis G, Fassolis A, et al. Benign paroxysmal positional vertigo in the elderly: current insights. Clin Interv Aging 2018;13:2251-2266. https://doi.org/10.2147/CIA.S144134

14 Jumani K, Powell J. Benign paroxysmal positional vertigo: management and its impact on falls. Ann Otol Rhinol Laryngol 2017;126:602-605. https://doi.org/10.1177/0003489417718847

15 Pérez Fernández N. Posturografía. In: Pérez Fernández N, ed. Atlas de pruebas vestibulares para especialistas en otorrinolaringología. 1st Ed. España. PROFARMACO.2. 2009, p. 81-99.

16 Zhang D-G, Fan Z-M, Han Y-C, et al. Clinical value of dynamic posturography in the evaluation and rehabilitation of vestibular function of patients with benign paroxysmal positional vertigo. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi 2010;45:732-736.

17 Kasse CA, Santana GG, Scharlach RC, et al. Results from the balance rehabilitation unit in benign paroxysmal positional vertigo. Braz J Otorhinolaryngol 2010;76:623-9. https://doi.org/10.1590/S1808-86942010000500015

18 Mastroleo I. Consideraciones sobre las obligaciones posinvestigación en la Declaración de Helsinki 2013. Rev. Bioética y Derecho 2014;31:51-65.

19 Kasse CA, Santana GG, Branco-Barreiro FCA, et al. Postural control in older patients with benign paroxysmal positional vertigo. Otolaryngol Head Neck Surg 2012;146:809-815. https://doi.org/10.1177/0194599811434388

20 Novoa C I, Pino UC, Donoso TS, et al. Mareo residual, una condición clínica frecuente posterior a maniobra de reposición exitosa en vértigo posicional paroxístico benigno: una revisión. Rev Otorrinolaringol Cir Cabeza Cuello 2020;80:201-208. http://dx.doi.org/10.4067/S0718-48162020000200201

21 Wolfson L, Whipple R, Derby CA, et al. A dynamic posturography study of balance in healthy elderly. Neurology 1992;42:2069-2069. https://doi.org/10.1212/WNL.42.11.2069

22 Faraldo-García A, Santos-Pérez S, Rossi-Izquierdo M, et al. Posturographic limits of stability can predict the increased risk of falls in elderly patients with instability? Acta Otolaryngol 2016;136:1125-1129. https://doi.org/10.1080/00016489.2016.1201591

23 Wu PX, Yang J, Huang XS, et al. Effect of dynamic balance during the onset of benign paroxysmal positional vertigo on residual dizziness after successful repositioning: a multicenter prospective cohort study. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi 2021;56:1277-1282. https://doi.org/10.3760/cma.j.cn115330-20210912-00607

24 Assal S, Morsy HM, Almagassbi NM, et al. Assessment of sensory organization testing in benign paroxysmal positional vertigo patients before and after repositioning manoeuvre. Acta Otorrinolaringol (Engl Ed) 2021. https://doi.org/10.1016/j.otorri.2021.04.007 [Online Ahead of Print].