Curtin School of Allied Health

Post Treatment Vertigo, Dizziness, and Unsteadiness in Older Adults with Benign Paroxysmal Positional Vertigo

Eyvonne Siew Siean Sim

0000-0002-2661-476X

This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

April 2021

Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics (For projects involving human participants/tissue, etc) The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from both SingHealth Centralised Institutional Review Board (CIRB), Approval Number CIRB Ref: 2016/2799; and the Curtin University Human Research Ethics Committee (EC00262), Approval Number HRE2017-0008.

Signature:

Eyvonne Sim Siew Siean

Date: 16 April 2021

Acknowledgement

First and foremost, my heartfelt gratitude to my main supervisor, Professor Keith Hill, for his invaluable guidance, support, and kind patience, throughout my PhD journey. A big thank you to my co-supervisors, Dr Dawn Tan and Dr Pua Yong Hao, for their guidance, support, and unconditional friendship. I am also very grateful to Dr Leanda McKenna, Dr Kathy Briffa, A/Prof Daniel Gucciardi, and Dr Elissa Burton for their unrelenting support and help.

I am most grateful to the Curtin University Graduate Research School Faculty for awarding me the Curtin International Postgraduate Research Scholarship (CIPRS)/Health Sciences Faculty International Research Scholarship (HSFIRS). I would also like to acknowledge the fund support provided by the Singapore General Hospital (SGH) Research Grant (SRG_NIG, awarded to Dr Dawn Tan, Co-supervisor).

A big thank you to SGH Physiotherapy Department and the Department of Otolaryngology including the doctors, nurses, and clinic assistants. Special thank you to Dr Yip Chun Wai (Neurologist, National Neuroscience Institute) and Dr Chan Yew Meng (Otolaryngologist, SGH) for their invaluable time, knowledge, and support. A big thank you to Ms Khuzaimah Saini (SGH Audiometry) for her encouragement and sharing of knowledge and expertise.

Deep appreciation for Mr David Smithson (former International Sales Director, GN Otometrics A/S) for his generosity and trust in loaning me the ICS Impulse vHIT for this PhD project. Huge thank you to Mr Thomas Tang and Ms Michelle Teh of Surgipro Pte Ltd for their tireless support (training and administrative matters).

I am so grateful to all the study participants. Without them, I would not have been able to complete my studies. They were always kind and encouraging. Despite their health problems and busy schedule, they dedicated their time and efforts to participating in this research so they could help others with similar problems.

To my beloved husband and daughter, my pillars of strength, I thank them for their unconditional love, support, and patience which kept me going. To my parents, siblings, and everyone in the family, thank you for the love and support.

To God, thank you for protecting, sustaining, and guiding me. Thank you for all the blessings and for everything bestowed upon me.

Acknowledgement of Country

We acknowledge that Curtin University works across hundreds of traditional lands and custodial groups in Australia, and with First Nations people around the globe. We wish to pay our deepest respects to their ancestors and members of their communities, past, present, and to their emerging leaders. Our passion and commitment to work with all Australians and peoples from across the world, including our First Nations peoples are at the core of the work we do, reflective of our institutions' values and commitment to our role as leaders in the Reconciliation space in Australia

Acronyms and Abbreviations

ABC	Activities-specifc Balance Confidence Scale
BDE	Brandt-Daroff exercise
BPPV	Benign Paroxysmal Positional Vertigo
CI	Confidence Interval
CRM	Canalith Repositioning Manoeuvre
CRP	Canalith Repositioning Procedure
cVEMP	Cervical Vestibular Evoked Myogenic Potentials test
DHI	Dizziness Handicap Inventory
DHP	Dix-Hallpike
DGI	Dynamic Gait Index
FPP	Forced Prolonged Position
GAI	Geriatric Anxiety Inventory
GDS-15	15-Item Geriatric Depression Scale
HAP	Human Activity Profile
htDVA	Head Thrust Dynamic Visual Acuity test
IQR	Interquartile Range
LPR	Line of Polarity Reversal
M	Mean
MCID	Minimal Clinically Important Difference
mCTSIB	Modified Clinical Test of Sensory Integration on Balance
MDC	Minimal Detectable Change
Mdn	Median
OR	Odds Ratio
oVEMP	Ocular Vestibular Evoked Myogenic Potentials test
PICF	Participant Information and Consent Form
QE	Quasi-experimental study
RCT	Randomised Controlled Trial
RR	Relative Risk
SD	Standard Deviation
SEM	Standard Error of Measurement
SEM	Standard Error of Mean
SF36	36-Item Short Form Survey
SOT	Sensory Organisation Test
VCR	Vestibulo-collic Reflex
VEMP	Vestibular Evoked Myogenic Potentials test
vHIT	Video Head Impulse Test
VOR	Vestibulo-ocular reflex
VSR	Vestibulo-spinal reflex
VRBQ	Vestibular Rehabilitation Benefits Questionnaire

Abstract

Benign Paroxysmal Positional Vertigo (BPPV) is a common cause of peripheral vertigo and is more prevalent in older people. Some patients may develop residual dizziness and anxiety despite successful repositioning manoeuvres. It is unclear what factors are associated with residual dizziness in older people. Evidence on treatment outcomes is also conflicting and patients' experiences have not been explored. The research aims to address these evidence gaps and gain insight into the rehabilitation outcomes/experiences and residual dizziness in older adults with BPPV. This thesis comprises a systematic review, two cross-sectional- and one longitudinal- studies, and a qualitative research arm. The results show that initial repositioning manoeuvres may not be as effective in older adults with BPPV. However, BPPV resolution is generally achieved in the longer term. Many of the participants also experienced recurrence and residual dizziness following BPPV resolution. Residual dizziness in older adults with BPPV was associated with advanced age and anxiety-, and depression- measures. Residual dizziness was also associated with subjective outcomes such as quality of life, balance confidence and mental health but not with physical activity level and physical outcomes such as gait speed and balance. The qualitative study highlighted that BPPV negatively impacts on both the physical and emotional health of these older adults with BPPV. Many of them perceived an increased risk of falls and threat to their safety with the BPPV symptoms, and often chose to avoid any triggering activities or movements. The participants reported improvements in both symptoms and function with treatment, although the majority remained anxious and cautious. In conclusion, older adults with BPPV are affected both physically and emotionally. Recurrence and residual dizziness are also common in this patient group. Results highlight the need for broader screening of mental health, balance impairment, and fall risk to be included in routine assessments of older adults with BPPV. Patient education and longer follow-up time are also integral for optimizing recovery in this patient population.

Table of Contents

Declaration ii
Acknowledgement iii
Acknowledgement of Country iv
Acronyms and Abbreviations v
Abstract vi
Table of Contents vii
List of Tables xiv
List of Figures xvi
Chapter 1 Introduction 1
1.1 Background 1
1.2 Research Objectives 5
1.3 Outline of the Thesis 6
Chapter 2 Literature Review 8
2.1 The Vestibular System 8
2.1.1 The peripheral vestibular apparatus 9
2.1.2 Effects of ageing 12
2.1.3 Vestibular dysfunction and functional impact 15
2.2 Benign Paroxysmal Positional Vertigo 16
2.2.1 Proposed pathomechanism for BPPV 17
2.2.2 Diagnosis 18
2.2.3 Management 26
2.3 Older Adults and BPPV 37
2.3.1 Current evidence and gaps 38
2.4 Summary of Literature Review 41
Chapter 3 Poor Treatment Outcomes following Repositioning Manoeuvres in Younger and Older Adults with Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis 43
3.1 Abstract 44
Objective: 44

Data sources: 44
Review methods: 44
Results: 44
Conclusions and Implications: 44
Keywords 45
3.2 Introduction 46
3.3 Methods 47
3.4 Results 49
3.4.1 Study selection 49
3.4.2 Subject and study characteristics 50
3.4.3 Intervention 81
3.4.4 Outcomes 81
3.4.5 Methodological quality (see Tables 3.3a, 3.3b and 3.3c) 82
3.4.6 Results of individual studies 87
3.4.7 Comparison of outcomes between older and younger adult groups: Meta-analysis 89
3.5 Discussion 98
3.6 Conclusion and Implications 99
Chapter 4 Methods 101
4.1 Introduction 101
4.2 Research Design 101
4.3 Participants 102
4.3.1 Inclusion criteria 103
4.3.2 Exclusion criteria 104
4.3.3 Recruitment details 104
4.4 Assessments 106
4.4.1 Overview 106
4.4.2 Vestibular Rehabilitation Benefits Questionnaire (VRBQ) 110

4.4.3 Visual Analogue Scale (VAS) for intensity of vertigo, dizziness, and unsteadiness 115
4.4.4 Walking speed (m/s) 116
4.4.5 Positional tests 119
4.4.6 Video Head Impulse Test (vHIT) 122
4.4.7 Modified Clinical Test of Sensory Integration on Balance (mCTSIB) 123
4.4.8 Activities-specific Balance Confidence Scale (ABC) 124
4.4.9 Number of falls 124
4.4.10 Human Activity Profile (HAP) 125
4.4.11 Geriatric Depression Scale-15 (GDS-15) 126
4.4.12 Geriatric Anxiety Inventory (GAI) 126
4.4.13 Sensory Organisation Test (SOT) (replaced with mCTSIB, see section 4.4.7) 127
4.4.14 Dynamic Gait Index (DGI) (removed) 127
4.5 Sample Size Calculation and Feasibility 128
4.6 Qualitative Study 129
4.7 Data Analysis 131
4.7.1 Quantitative studies 131
4.7.2 Qualitative study 133
4.8 Ethical Considerations 134
4.8.1 Informed consent 134
4.8.2 Participant safety and rights 135
4.8.3 Confidentiality of data and patient records 136
Chapter 5 Physical Performance and Mental Health of Older Adults with BPPV versus Comparison Controls Before and After Repositioning Manoeuvres (Cross-sectional Studies 1 and 2) 137
5.1 Abstract 137

5.2 Introduction 137
5.3 Objectives 139
5.4 Methods 140
5.4.1 Participants 140
5.4.2 Procedure 141
5.5 Statistical Analysis 143
5.6 Results 144
5.6.1 Participant profile 144
5.6.2 Group comparison at baseline (T0) (BPPV and comparison control) 147
5.6.3 Change in BPPV group and comparison of results with comparison controls at first follow-up (T1) 150
5.6.4 Factors associated with residual dizziness 161
5.7 Discussion 164
5.8 Conclusion 168
Chapter 6 Longitudinal Study of Recovery from BPPV in Older Adults 170
6.1 Abstract 170
6.2 Introduction 171
6.3 Objectives 173
6.4 Methods 173
6.5 Statistical Analysis 176
6.5.1 Missing data management 176
6.5.2 Data analysis 180
6.6 Results 182
6.6.1 Overview 182
6.6.2 Changes in BPPV status and recurrences 184
6.6.3 Factors associated with residual dizziness at 6 months 188

6.6.4 Physical performance and self-report measures associated with dizziness and unsteadiness at 6 months 192
6.7 Discussion 195
6.8 Conclusion 201
Chapter 7 A Qualitative Study Exploring the Experiences of Older Adults with Benign Paroxysmal Positional Vertigo 203
7.1 Abstract 203
7.2 Introduction 203
7.3 Objectives 205
7.4 Methods 205
7.4.1 Design 205
7.4.2 Participants 206
7.4.3 Procedure 206
7.4.4 Data analysis 207
7.5 Results 207
7.5.1 Physical and functional impacts 210
7.5.2 Psycho-emotional and social impacts 213
7.5.3 Treatment and recovery 217
7.5.4 BPPV literacy 220
7.6 Discussion 222
7.7 Conclusion 227
Chapter 8 Discussion and Conclusion 228
8.1 Summary of Key Findings 228
8.2 Discussion 231
8.2.1 Effectiveness of repositioning manoeuvres in older adults with BPPV 231
8.2.2 Residual dizziness in older adults with BPPV 232

8.2.3 Incorporating assessment of other domains in BPPV management 234
8.2.4 Follow-up assessments and treatment 234
8.2.5 Falls monitoring and prevention 235
8.2.6 The experiences of older adults with BPPV 236
8.2.7 Accessibility to treatment for BPPV 237
8.3 Limitations 237
8.4 Recommendations 239
8.4.1 Clinical practice 239
8.4.2 Future research 240
8.5 Conclusion 240
References 242
Appendices 288
Appendix A Poor Treatment Outcomes following Repositioning Manoeuvres in Younger and Older Adults with Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis 288
Appendix B. Attribution Statement 311
Appendix C. Copyright Statement 312
Appendix D. Vestibular Rehabilitation Benefits Questionnaire (VRBQ) Scoring Template 313
Appendix E. The Activities-specific Balance Confidence Scale (ABC) 315
Appendix F. The Human Activity Profile (HAP) 318
Appendix G. The 15-Item Geriatric Depression Scale (GDS-15) 323
Appendix H. The Geriatric Anxiety Inventory (GAI) 324
Appendix I. Email correspondence from the UniQuest eShop for the use of Geriatric Anxiety Inventory (GAI) in this thesis 326
Appendix J. The Dynamic Gait Index (DGI) 329
Appendix K. SingHealth Centralised Institutional Review Board (CIRB) Approval Letter 332

Appendix L. Curtin University Human Research Ethics Committee (HREC) Approval Letter 335

Appendix M. The Participant Information Sheet and Consent Form (PICF) (version 6, 14 February 2019) 337

Appendix N. List of guiding interview questions used in the semi-structured interviews in the Qualitative Study (Chapter 7) 345

List of Tables

Table 2.1 Right Dix-Hallpike test: Possible BPPV signs and diagnoses 22
Table 2.2 Horizontal canalithiasis and cupulolithiasis: Characteristics of nystagmus with the Roll test 25
Table 2.3 Additional confirmatory tests to decide on the affected side in horizontal canal canalithiasis and cupulolithiasis 26
Table 3.1 Search strategy adapted for Pubmed 48
Table 3.2 Summary of study characteristics and results 53
Table 3.3a. Quality appraisal of randomised controlled trials using JBI Critical Appraisal Tools 83
Table 3.3b. Quality appraisal of quasi-experimental studies using JBI Critical Appraisal Tools 84
Table 3.3c. Quality appraisal of cohort studies using JBI Critical Appraisal Tools ... 86
Table 3.4. Comparison of treatment outcomes for younger and older adult groups with normative/comparison data 90
Table 4.1 Assessment procedures (original protocol) and timeline for both BPPV and comparison control groups 108
Table 4.2 Original and amended assessment protocol 109
Table 5.1. Comparison of characteristics between the BPPV group and the comparison control group 145
Table 5.2. Comparison of outcomes between the BPPV group and the comparison control group at baseline (T0) with adjustment for age, gender, and number of comorbidities 148
Table 5.3. Comparison of outcomes between the follow-up BPPV-positive group (T1 BPPV-positive) and the comparison control group with adjustment for age, gender, and number of comorbidities 152
Table 5.4 Adjusted mean differences between T1 BPPV-positive and comparison control groups and MCID scores for comfortable walking speed with horizontal head turns and VRBQ Anxiety subscale 155
Table 5.5 Comparison of outcomes between the follow-up BPPV-negative group (T1 BPPV-negative) and the comparison control group with adjustment for age, gender, and number of comorbidities 157

Table 5.6 Outcomes with adjusted mean differences between T1 BPPV-negative and comparison control groups, and MCID scores 160
Table 5.7. Results of regression models exploring factors associated with residual dizziness at follow-up (T1) assessment (*N* = 40) 162
Table 6.1 Table of proportion of missing data of variables (out of 154* observations for each variable) 178
Table 6.2 Table of complete and subjective only assessments, and missing cases at various timepoints for BPPV group 184
Table 6.3 Results of physical and self-report outcome measures for the BPPV sub-groups at T1 (start of longitudinal study) 185
Table 6.4 Factors associated with dizziness and unsteadiness in older adults who were treated for BPPV at 6 months 191
Table 6.5 Association of dizziness and unsteadiness with physical performance and self-report measures in older adults who were treated for BPPV at 6 months 194
Table 7.1 Participant demographics and BPPV status 208

List of Figures

Figure 2.1 The vestibular organ and the pathomechanisms of BPPV 10
Figure 2.2 Epley manoeuvre for the treatment of right posterior canalithiasis 28
Figure 3.1 PRISMA flow diagram for the screening process 51
Figure 3.2a. Forest plot showing results of studies in the younger (< 60 years old) and older (⩾ 60 years old) groups for the change in Dizziness Handicap Inventory scores between baseline and final assessments post repositioning manoeuvres 94
Figure 3.2b. Forest plot showing results of studies in the younger and older adult groups for changes in static and dynamic balance after repositioning manoeuvres 96
Figure 3.3a. Forest plot showing results of studies in the younger adult (<60 years old) group for recurrence 97
Figure 3.3b. Forest plot showing results of studies in the older adult (⩾ 60 years old) group for recurrence 97
Figure 4.1 Study flow diagram 102
Figure 4.2 Vestibular Rehabilitation Benefits Questionnaire (VRBQ) 111
Figure 4.3 The Visual Analogue Scale for dizziness, vertigo and unsteadiness set up for this study (as accessed on the SingHealth Redcap database) 116
Figure 4.4 The GaitRite® electronic mat 118
Figure 4.5 The ICS Impulse (GN Otometrics) goggles and software 121
Figure 4.6 Slow phase velocity captured during left roll test 121
Figure 4.7 Horizontal vHIT with right head impulse test tracing shown on the screen 123
Figure 4.8 The Effective Sample Size Formula 129
Figure 5.1 Flowchart showing the study timepoints and components for Cross-sectional Studies 1 and 2 141
Figure 5.2 Diagram showing the BPPV status and distribution of participants after initial repositioning manoeuvres 150
Figure 6.1 Diagram of longitudinal study timelines 174
Figure 6.2 Density plot showing distribution of both original and imputed values for comfortable walking speed with horizontal head turns 179

Figure 6.3 Convergence plots for positional test result (positive/negative), the slow phase velocity, and maximum/fast walking speed – showing the mean and standard deviations of the imputed values against the number of iterations for the imputed data 180
Figure 6.4 Number of participants for both BPPV and comparison control groups at each follow-up for this longitudinal study 183
Figure 6.5 Diagram depicting the changes in BPPV status over 6 months 187
Figure 6.6 Number of falls between BPPV and comparison control groups..... 188
Figure 6.7 Forest plot of adjusted estimate differences for various factors in association with residual dizziness and unsteadiness at 6 months 190
Figure 6.8 Effects of age on VAS dizziness based on regression model 190
Figure 6.9 Partial plot of comfortable walking speed with horizontal head turns (HHT) associated with VAS dizziness at 6 months..... 193
Figure 6.10 Partial plot of comfortable walking speed with horizontal head turns associated with VAS unsteadiness at 6 months 193
Figure 7.1 Diagram of main themes and sub-themes generated from the interview data..... 209

Chapter 1 Introduction

1.1 Background

Benign Paroxysmal Positional Vertigo (BPPV) is one of the most common causes of peripheral dizziness. The 1-year- incidence and prevalence of BPPV were reported to be 0.6% and 1.6% (von Brevern et al., 2007). Benign Paroxysmal Positional Vertigo can occur at any age; but its prevalence is seven times higher in adults above 60 years old, compared with those between 18 to 39 years old (von Brevern et al., 2007). Most cases of BPPV are idiopathic but trauma, Meniere's disease, migraine, vestibular labyrinthitis/neuritis and ear surgery are other possible causes (Herdman & Hoder, 2014; Parnes & Nabi, 2009). The pathology happens when otoconia dislodge from the utricular macular surface and travel into the semicircular canal(s) (Parnes & Nabi, 2009). When the head moves into a certain position, the otoconia in the semicircular canal move and displace the endolymph, causing cupular deflection. This causes the person to experience a brief intense episode of vertigo. A characteristic nystagmus, lasting the same duration as the vertigo, can often be concurrently observed. Other symptoms may include nausea, vomiting, postural and gait instability, and light-headedness (Herdman & Hoder, 2014).

The diagnosis of BPPV is confirmed through detailed history taking and positional tests (Parnes & Nabi, 2009). The patient with BPPV may complain of a sudden onset of intense vertigo triggered by a change in head position. Typical activities include rolling in bed, lying down or getting up in bed, looking up, and bending forward or down (Herdman & Hoder, 2014). The vertigo usually lasts less than a minute but may be intense enough to result in loss of balance and in some cases, falls. Positional tests (Dix-Hallpike/Side-lying/Roll tests) are confirmatory manoeuvres during which the patient's head is positioned to align the specific semicircular canal(s) with gravity to induce otoconial movement (Herdman & Hoder, 2014). The therapist observes for nystagmus (direction, latency, and duration) and monitors the patient's symptoms. Repositioning manoeuvres are the gold standard treatment for BPPV (Bhattacharyya et al., 2017). Treatment involves moving the patient's head through a series of positions with the aim of moving the otoconia out of the affected semicircular canal and back into the vestibule. The specific

repositioning manoeuvre used depends on the semicircular canal (posterior, horizontal or anterior) and the pathomechanism (canalithiasis or cupulolithiasis) involved.

The effectiveness of repositioning manoeuvres is generally well proven. The most well-researched treatment is the Epley manoeuvre, which has an efficacy rate of over 90% in just one to two treatment sessions (Babac & Arsovic, 2012; Sridhar, Panda, & Raghunathan, 2003). The reported success rates for the other repositioning manoeuvres ranged from 60% to over 90% (T. D. Fife et al., 2008). These success rates were predominantly quantified by a positive-to-negative positional test and/or improved subjective symptom or handicap reporting. Notwithstanding the importance of BPPV resolution and amelioration of symptoms in the management of BPPV, the other affected domains (physical/functional, vestibular function, quality of life, and mental health outcomes) may impact on the overall recovery of these patients. These outcomes are less explored in the BPPV literature; therefore, it will be beneficial to gather more evidence on how they are impacted by BPPV and repositioning manoeuvres; and if further interventions are needed for these domains in the management of patients with BPPV. Symptoms such as vertigo, postural and gait instability, and light-headedness further heighten the risk of falls in this population. Moreover, BPPV was often mis- or under-diagnosed in older adults with dizziness and balance problems (Oghalai, Manolidis, Barth, Stewart, & Jenkins, 2000; Tuunainen et al., 2011). Compared with younger counterparts, older adults with BPPV were more likely to report dizziness and unsteadiness, instead of the classic symptom of vertigo (Plodpai, Atchariyasathian, & Khaimook, 2014). With an increasingly ageing global population, optimal management of this common but poorly recognised, yet easily treatable condition is critical in minimising unnecessary healthcare costs and preserving quality of life.

The efficacy of repositioning manoeuvres in older adults has been reported to be high (> 90%) (André, Moriguti, & Moreno, 2010; Salvinelli et al., 2004; Vaz, Gazzola, Lanca, Dorigueto, & Kasse, 2013). Age was not found to be associated with treatment failure (Monobe, 2001). Kao et al (2009) compared the treatment results between younger adults (< 65 years old) and older adults ($\geqslant$ 65 years old). The authors reported no age differences in the success and recurrence rates as well as subjective activity limitations (social activity/work/household activity) and activity

difficulties (walking/balance/falls) (Kao et al., 2009). Vaz et al (2013), in their study on older adults with BPPV, found significant improvement in the symptoms, Timed Up and Go test (TUG), and the Clinical Test of Sensory Integration on Balance test (CTSIB) post BPPV resolution following Epley manoeuvres. In contrast, some studies reported that repositioning manoeuvres were not as effective in older adults (Babac, Djeric, Petrovic-Lazic, Arsovic, & Mikic, 2014; Batuecas-Caletrio et al., 2013; Silva, Ribeiro, Freitas, Ferreira, & Guerra, 2016). Balance recovery in the older adult post repositioning manoeuvres was not optimal in all aspects (Silva et al., 2016). One study found that the improvement in balance in older adults post repositioning manoeuvres was not sustained 12 months later and had returned to pre-treatment values (Lanca et al., 2013). Some studies also found that BPPV recurrence was higher in older adults (Batuecas-Caletrio et al., 2013; Prokopakis et al., 2013).

After successful repositioning manoeuvres, some people may continue to experience non-vertiginous dizziness and/or unsteadiness despite being free of BPPV. The prevalence of residual dizziness in adults with BPPV was reported to be between 31% to 63% (Abou-Elew et al., 2011; Faralli, Lapenna, Giommetti, Pellegrino, & Ricci, 2016; Seok, Lee, Yoo, & Lee, 2008; Teggi, Giordano, Bondi, Fabiano, & Bussi, 2011; Teggi, Quaglieri, Gatti, Benazzo, & Bussi, 2013). Some factors linked to residual dizziness include duration of BPPV symptoms before treatment, otoconial debris remaining in the semicircular canal (but too small to induce vertigo and nystagmus), poor vestibular adaptation after treatment, utricular/otolithic dysfunction, co-existing vestibular conditions, and anxiety (Giommetti et al., 2017; Teggi & Nuti, 2017). Regarding age effect in residual dizziness after repositioning manoeuvres, the evidence so far has been conflicting. Some studies found no association between age and residual dizziness (Abou-Elew et al., 2011; N. H. Lee, Kwon, & Ban, 2009; Seok et al., 2008) while other studies suggested an association between age and residual dizziness (Martellucci et al., 2016; Teggi et al., 2011; Vaduva, Esteban-Sanchez, Sanz-Fernandez, & Martin-Sanz, 2018). Overall, there is a paucity of studies on residual dizziness in the older adult population. Much remains unknown about the prevalence of residual dizziness in older adults as well as the factors that predispose them to residual dizziness post successful BPPV treatment. Another area that should be investigated is the impact of residual dizziness on older adults with BPPV – how does this affect them physically, functionally, and psycho-emotionally?

A study on older adults with vestibular problems found that vertigo (or dizziness) was the most common cause of falls and was also associated with two or more falls (Ganança, Gazzola, Aratani, Perracini, & Ganança, 2006). Data from a falls clinic, where 1/3 of patients complained of dizziness, revealed that patients with BPPV were more likely to fall (44%) compared to patients with other forms of dizziness (28%); and falls were also significantly higher in the older age groups (Lawson, Bamiou, Cohen, & Newton, 2008). Gananca et al (2010) reported that there was a significant decrease in the number of falls in older adults with BPPV after repositioning manoeuvres. However, 85% of these older adults continued to fall in the 12 months post treatment (Gananca et al., 2010). A recent study investigated falls in older adults (> 65 years old) who were referred primarily for falls but were found to have BPPV (Jumani & Powell, 2017). After repositioning manoeuvres, the number of falls in this group of subjects decreased significantly by 64% (128 → 46 falls, $p < .001$). The authors also reported that subjects with comorbidities had significantly more falls than subjects without comorbidities (Jumani & Powell, 2017). It is well known that falls can result in unfavourable consequences such as fear of falling, depression and anxiety, activity restrictions, injuries, and even death. Despite the increased falls risk posed by BPPV, falls data in older adults with BPPV remain scarce. More information in this area will be helpful in directing falls prevention measures and programmes for this patient group.

The episodic vertigo attacks in BPPV are very short in duration (< one minute) but can be very sudden and intense. Acute vertigo can cause extreme anxiety as well as feelings of disproportionate disability in its sufferers (Pollak, Klein, Rafael, Vera, & Rabey, 2003). Previous studies have shown that subjects with BPPV demonstrated high levels of negative emotions and anxiety (Gunes & Yuzbasioglu, 2019; Hagr, 2009; Kahraman, Arli, Copoglu, Kokacya, & Colak, 2017; Pollak, Segal, Stryjer, & Stern, 2012). Even when these subjects were successfully treated and free of BPPV, these negative feelings and anxiety persisted (Gunes & Yuzbasioglu, 2019; Kahraman et al., 2017; Pollak et al., 2012). These studies were conducted on adults with BPPV and of all ages. There is a lack of information on mental health outcomes such as anxiety and depression specific to older adults with BPPV. This is important as older adults with BPPV may also suffer from other types of dizziness and/or comorbidities, increasing the likelihood of them developing depression and anxiety. Mental health issues such as depression and anxiety can negatively affect

rehabilitation outcomes (Honaker, Gilbert, Shepard, Blum, & Staab, 2013). Studies have also found links between anxiety and falls-related psychological concerns (fear of falling, balance confidence, and falls efficacy) (Payette, Belanger, Leveille, & Grenier, 2016) as well as residual dizziness (Martellucci et al., 2016; Teggi et al., 2011). These study findings point to the influence and importance of mental health, and the need to adopt a more holistic approach in the studies and management of older adults with BPPV.

Understanding the impact of BPPV, its diagnosis and management and longer-term impacts from the perspectives of older persons with BPPV would also provide valuable data to inform practice and improve management. Healthcare providers and patients may not always share or envision the same treatment goals and outcomes. What the healthcare provider perceives as a satisfactory patient experience may not turn out to be gratifying to the patient. Data on patient perspective through qualitative methods would provide salient information to allow for the reflection and review on the current management and identification of gaps, with the aims of improving the future care and experiences of older adults with BPPV.

This PhD programme aimed to gain an understanding of residual dizziness and comprehensive insights into the perceptions and treatment outcomes of older adults with BPPV. The findings will help in the evaluation of the current BPPV management for older adults, including possible health system structural issues faced by them. The evidence may also provide some future research directions pertaining to BPPV and its management in the older adult population.

1.2 Research Objectives

Overall, this thesis aimed to:

(i) Critically review the current evidence on treatment outcomes after repositioning manoeuvres in adults with BPPV; and establish if older adults with BPPV experience poorer outcomes compared with younger counterparts (Chapter 3).

(ii) Compare measures of vestibular function, balance and gait, balance confidence, falls risk, and mental health in older adults with BPPV, with comparison controls (Chapter 5).

(iii) Explore the effectiveness of initial repositioning manoeuvres in older adults with BPPV (Chapter 5).

(iv) Compare measures of vestibular function, balance and gait, balance confidence, falls risk, and mental health of both BPPV-positive and BPPV-negative groups *after initial repositioning manoeuvres*, with comparison controls (Chapter 5).

(v) Identify the factors associated with residual dizziness despite a negative Dix-Hallpike test, *after initial repositioning manoeuvres* in older adults with BPPV (Chapter 5).

(vi) Identify the factors associated with residual dizziness and unsteadiness in older adults who were treated for BPPV at six-month follow-up (Chapter 6).

(vii) Identify the physical/functional and self-report measures associated with residual dizziness in older adults who were treated for BPPV at six-month follow-up (Chapter 6).

(viii) Evaluate trends of recurrence and changes in BPPV status in older adults with BPPV over six months follow-up (Chapter 6).

(ix) Conduct an exploratory investigation of whether older adults with BPPV experience more falls compared with comparison controls, over the six-month period following repositioning treatment (Chapter 6).

(x) Explore the experiences of older adults on how BPPV and its management affected them (Chapter 7).

1.3 Outline of the Thesis

This thesis comprises a total of eight chapters:

The current chapter (Chapter 1) provides a brief overview of the topic addressed by this thesis. The objectives of the thesis and the outline of the thesis chapters are also presented.

Chapter 2 presents a review on the background information and current literature pertaining to the vestibular system and BPPV (pathomechanism, assessment, and management) with a focus on the older adult population.

Chapter 3 is a systematic review and meta-analysis on the comparison of poor treatment outcomes following repositioning manoeuvres between the younger

and older adults with BPPV. This paper (Sim, Tan, & Hill, 2019) was published online in the Journal of the American Medical Directors Association (See Appendix A).

Chapter 4 describes the methods used in the various studies of this thesis. Details on subject selection and recruitment, sample size calculation, outcome measures, data collection, and ethics considerations are presented.

Chapter 5 presents the methods, results, and discussion of both cross-sectional studies 1 and 2. The results from the physical and subjective performance of older adults with BPPV are compared with that of the comparison controls. Factors associated with residual dizziness in older adults with BPPV are also discussed.

Chapter 6 presents the methods, results, and discussion of the longitudinal study for older adults who had undergone treatment for BPPV. The patterns of change in BPPV status, falls data, and residual dizziness (including possible associated factors, and associated physical and subjective outcomes) over six months are also described.

Chapter 7 reports the qualitative study on exploring the experiences of older adults with BPPV to learn how they had been affected by BPPV and the treatment journey.

Chapter 8 is the final chapter that summarises and discusses the findings, the clinical implications on the care of older adults with BPPV, and the future research directions in this area.

Chapter 2 Literature Review

This chapter provides the background knowledge on which the thesis topic is based on. It starts off with a brief general introduction to the human vestibular system. This is followed by a more detailed write-up on the foci of this thesis: the peripheral vestibular system and a common peripheral vestibular condition, Benign Paroxysmal Positional Vertigo (BPPV). Current literature and evidence on the diagnosis and treatment of BPPV as well as the management of BPPV in older adults, are discussed.

2.1 The Vestibular System

Imagine

a jogger along a path by the seaside, running and enjoying the surrounding view. With each step forward, the body is in constant motion and the head turns every now and then when something catches the eyes. How is the jogger able to stay upright and not fall over with the constant motion? How does his vision stay clear with the small but constant displacement of the body and head?

The answer lies in our vestibular system. *The human vestibular system helps to maintain stable vision during head movements. It is also involved in the maintenance of an upright posture and postural control.*

The vestibular system can be divided into three main components: the peripheral vestibular apparatus, the central vestibular processing centres, and the motor outputs (Hain & Helminski, 2014). Information from the peripheral vestibular apparatus, along with other sensory information (visual and somatosensory), are processed mainly at the vestibular nuclei. The four vestibular nuclei are situated in the pons. The vestibular nuclei also have extensive connections with the cerebellum, the ocular nuclei, and the brainstem for the mediation of the vestibulo-ocular (VOR), the vestibulo-collic (VCR), and the vestibulo-spinal (VSR) reflexes and activation of the extraocular and skeletal muscles. Apart from signals transmitted by the vestibular nuclei, the cerebellum also receives information directly from the peripheral vestibular apparatus. The cerebellum regulates the vestibular output to the motor

system and improves the efficiency of the motor outputs for gaze and postural control (Hain & Helminski, 2014). Gaze stability during head movements is maintained through the vestibulo-ocular reflex (VOR). The vestibulo-collic reflex (VCR) works on the neck muscles to improve head stability. Posture and postural control are achieved through the vestibulo-spinal reflex (VSR).

Any disruption or damage to the part(s) of the vestibular system may result in vertigo, dizziness, oscillopsia, nausea and vomiting, impaired balance, and hearing problems. These may lead to loss of function, disruption to daily activities/work, falls, and decreased quality of life.

2.1.1 The peripheral vestibular apparatus

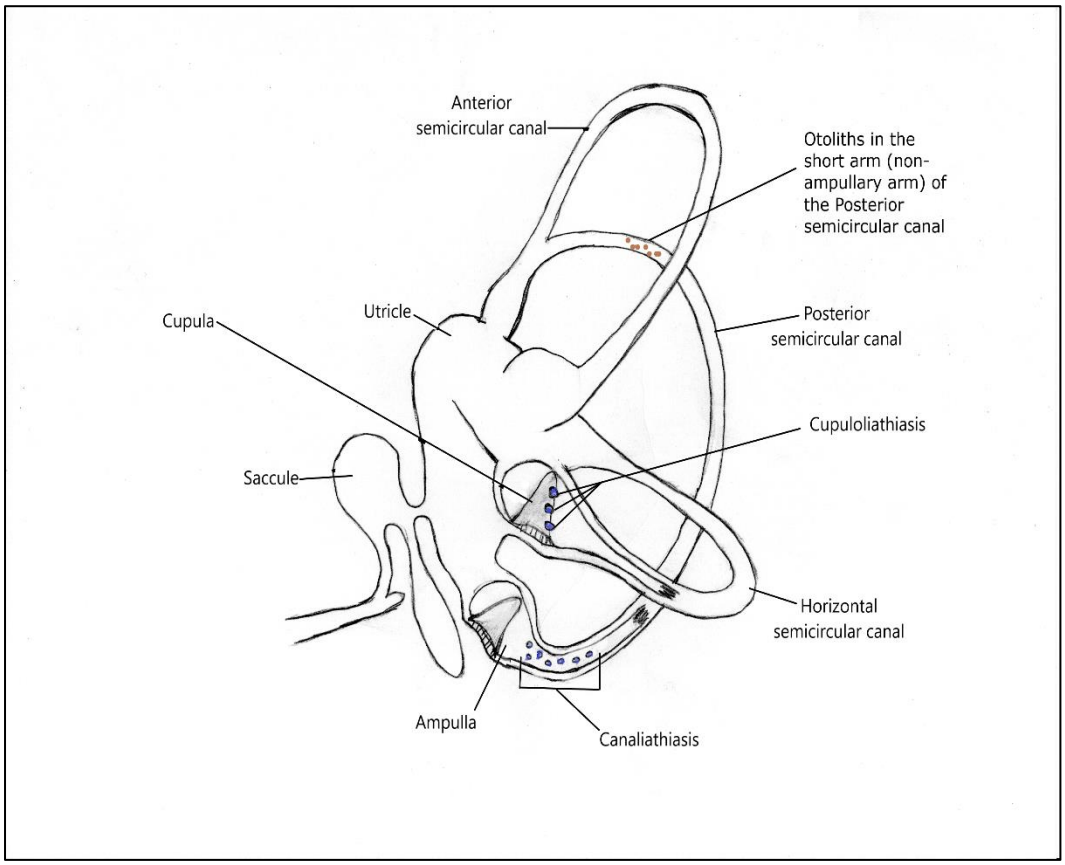
The vestibular apparatus is situated in the inner ear and extends from the cochlea (Hain & Helminski, 2014). It exists as a pair with one in each ear. Each vestibular apparatus is made up of a bony labyrinth of three interconnected semicircular canals and the vestibule. The membranous labyrinth sits within the bony labyrinth, supported by the perilymphatic fluid and connective tissue. Within the membranous labyrinth is the endolymphatic fluid which differs in chemical composition from the perilymphatic fluid (Hain & Helminski, 2014). The perilymph resembles the cerebrospinal fluid while the endolymph resembles the intracellular fluid. The membranous labyrinth contains the vestibular sensory organs: the semicircular canals and the otolithic organs.

2.1.1.1 The semicircular canals

The three semicircular canals are positioned at right angles to each other and in different spatial orientation: anterior, posterior, and horizontal (lateral) (see Figure 2.1). Each semicircular canal is widened at one end and this widening is known as the ampulla (Hain & Helminski, 2014). Inside the ampulla are the hair cells which send signals regarding head motion to the brain. The hair cells sit on a bed of blood vessels, nerve fibres and a gelatinous supporting tissue, the “crista ampullaris”. The crista ampullaris extends and envelops the hair cells forming a cupula, which separates the hair cells from the endolymph. It also occludes the ampulla from the adjacent vestibule. When the head moves, the endolymph within the semicircular canals moves and distorts the cupula. This bending of the cupula, hence the deflection of the hair cells within it, fires off neural signals to the brain. For the

horizontal canals, the bending of the cupula toward the ampulla (ampullopetal) sends off excitatory signals while bending away (ampullofugal) is inhibitory. The reverse is true for the vertical canals: ampullofugal flow is excitatory and ampullopetal flow is inhibitory (Hain & Helminski, 2014).

Figure 2.1 The vestibular organ and the pathomechanisms of BPPV



Note. Adapted from “Diagnosis and management of benign paroxysmal positional vertigo (BPPV)”, by L.S. Parnes, S.K. Agrawal, and J. Atlas, 2003, *CMAJ: Canadian Medical Association Journal*, 169(7), 683-685. Copyright 2003 by Canadian Medical Association or its licensors.

By virtue of their orientation, the semicircular canals detect and transmit information on rotational motions and angular velocities of the head. The semicircular canals are fairly aligned with the pulling directions of the extraocular muscles enabling the simple neural connectivity between the individual semicircular canals and the individual extraocular muscles (Hain & Helminski, 2014). The vertical canals (anterior and posterior) control the vertical and torsional eye movements. The horizontal canals control the horizontal eye movements. This is important in the vestibulo-ocular reflex (VOR) which works to keep the eyes in place for stable vision while the head is moving quickly. For example, if the head is turned quickly to the

right, the endolymph in the horizontal canals are displaced such that the right semicircular canal hair cells are depolarised and the left semicircular canal hair cells are hyperpolarised. The right vestibular nerve is stimulated and sends signals to the ipsilateral superior and medial vestibular nuclei in the brainstem, and the cerebellum. The vestibular nuclei fire both excitatory and inhibitory signals to the ocular motor nuclei on both sides. The result is the activation of the left lateral rectus and right medial rectus, and relaxation of the left medial rectus and right lateral rectus. This produces conjugate movements of the eyes to the left while the head turns to the right at a matching angular velocity. The optimal ratio of eye to head angular velocities (VOR Gain) is 1:1 (Wallace & Lifshitz, 2016). These compensatory slow-phase eye movements do not work optimally when the VOR function is decreased, hence resulting in small corrective saccade(s) towards the visual target (Bronstein, Patel, & Arshad, 2015). The cerebellum (flocconodular lobe) modulates the vestibular nuclei output as required to optimise the VOR gain (Khan & Chang, 2013).

The six semicircular canals work in pairs (three in each inner ear): (a) right and left horizontal, (b) right anterior and left posterior, and (c) right posterior and left anterior (Hain & Helminski, 2014). The planes of the paired canals are also very closely aligned. Head rotation in a certain plane will result in excitatory firing of one canal and inhibitory firing of the other paired canal. This push-pull relationship between the paired canals is advantageous for the following situations: (a) when one canal is not functioning well, the brain continues to receive information from the functioning paired canal; (b) “common mode rejection’’ referring to the concurrent firing of paired canals which is not caused by head motions but by changes in body temperature or neurochemistry; and (c) when rapid head movements are made (for example, during driving or sporting activities) resulting in vestibular overload and a quick compensation is needed (Hain & Helminski, 2014; Khan & Chang, 2013).

2.1.1.2 The otolithic organs

The otolithic organs (utricle and saccule) are located within the vestibule. Instead of angular velocities (as detected by the semicircular canals), the utricle and saccule sense information regarding linear head motions and accelerations (Hain & Helminski, 2014) (see Figure 2.1). The hair cells in the otolithic organs are found in the sensory epithelium known as “maculae”. The maculae sit on the floor of the utricle and on the medial wall of the saccule. In the maculae, the hair cells bodies sit

in a layer of supporting cells while the cilia extend into a gelatinous layer known as the “otolithic membrane”. Unlike the cupula, the otolithic membrane is weighted by a layer of otoconia (calcium carbonate crystals). This makes the otolithic membrane heavier than the surrounding tissues and more responsive to gravity and linear accelerations. For example, when the head tilts forward or laterally, gravity causes the heavier top layer of otolithic membrane to move. This shearing force bends and stimulates the hair cells. Likewise, linear motions, such as when one is in a travelling vehicle (horizontal) or lift (vertical), displace the weighted otolithic membrane and stimulate the hair cells.

Within the vestibule of an upright person, the utricle is positioned horizontally and the saccule vertically. Hence the utricle provides information on horizontal linear motions and accelerations while the saccule picks up information from motions and accelerations in the sagittal plane (Hain & Helminski, 2014; Khan & Chang, 2013). The utricular and saccular maculae are arranged such that they are mirror image of their counterparts in the opposite labyrinth. As with the semicircular canals, this arrangement allows for the push-pull relationship between the opposing maculae and enhances directional sensitivity to head motions. However, different from the uniform hair cell polarisations of the semicircular canals, each macula is made up of hair cells with opposing polarisations. These opposing hair cells are separated by the striola, which is a band around the line of polarity reversal (LPR) on the macula (Curthoys, 2020). With a specific direction of linear acceleration, one part of the macula will be depolarised while another part of the same macula will be hyperpolarised. This arrangement enables extra redundancy and minimises information loss with unilateral lesion of the otolithic organs.

2.1.2 Effects of ageing

There is well documented evidence that the structures and functions of the vestibular system decline with increasing age. Some age-related changes in the vestibular system include the loss of hair and supporting cells in the sensory organs, otoconial loss, and neuronal loss in the Scarpa’s ganglion and the Vestibular Nuclear Complex (Igarashi, Saito, Mizukoshi, & Alford, 1993; Lopez, Honrubia, & Baloh, 1997; Lopez et al., 2005; Merchant et al., 2000; Richter, 1980; Rosenhall, 1973; Ross, Peacor, Johnsson, & Allard, 1976). However, the studies reported differing temporal findings. Richter (1980) discovered that the sensory epithelia changes

preceded that of the Scarpa's ganglion, which usually start to escalate around 60 years of age. Compared to persons below 30 years old, significant decrease in hair cells have been reported in those aged 50 years and above. Another study (Merchant et al., 2000) reported a linear decrease in hair cell numbers with age, while a third study found significant hair cell loss in groups of subjects with average ages of 84- and 94- years old, respectively. Hair cell loss is found to be greater in the semicircular canals compared to the otolithic maculae (Lopez et al., 2005; Merchant et al., 2000; Rosenhall, 1973). Otoconial degeneration was found to start around middle age (50 to 60 years old) and the otoconial loss in the saccule was more significant compared to that in the utricle (Igarashi et al., 1993; Ross et al., 1976).

Tests of vestibular functions also demonstrated changes associated with ageing. Agrawal et al (2012) found significant difference in both semicircular canal- and otolithic organ- functions, between older adults (≥ 70 years old) and younger adults (≤ 50 years old), using the Head Thrust Dynamic Visual Acuity test (htDVA) and the Vestibular Evoked Myogenic Potentials test (VEMP). In the same study, the prevalence of deficits was highest in the semicircular canals (82% - 94%), followed by the saccule (54% - 62%) and the utricle (18% - 24%). However, the htDVA test results could have been confounded by oculomotor and cognitive process deficits (Agrawal et al., 2012). In view of confounding by other age-related non-vestibular factors, the Dynamic Visual Acuity test results may not be attributed solely to semicircular canal function (McGarvie et al., 2015).

Another commonly utilised test of semicircular canal function is the Head Impulse Test or the Video Head Impulse Test (vHIT). This is a test of the vestibular-ocular reflex: measuring the gain, which is the ratio of the mean velocity of eye movement to the mean velocity of head movement (MacDougall, Weber, McGarvie, Halmagyi, & Curthoys, 2009). McGarvie et al (2015) found no significant decline in VOR gains for both horizontal and anterior canals, with weak decline for posterior canal, across ages from 20s to 80s in healthy adults. The VOR gain for the horizontal canal was around 1.0 while the gains for the vertical canals were less than 1.0 for all ages (McGarvie et al., 2015). Mossman et al (2015) recorded statistically significant decline in horizontal canal VOR gain with age but noted that the decreases in gain per decade (0.012 and 0.017 at 80ms and 60ms respectively) were small. Another study on horizontal canal VOR gain found significant decrease of 0.012 per year starting from 80 years old after adjusting for gender, race, smoking

history, and comorbidities (C. Li, Layman, Geary, et al., 2015). Kim and Kim (2018) discovered significant decreases in horizontal canal- and vertical canals- VOR gains from 70 and 80 years of age, respectively. However, it should be noted that while the differences in gains between subjects in their 70s and those below 70 years old were significant in this study, the VOR gain results were similar to that found in the study by McGarvie et al (2015), and within acceptable limits of 0.8 to 1.2 (Curthoys & Manzari, 2017). In general, testing should include high velocity head impulses as the unaffected ear can compensate and yield a normal gain with low velocity head impulses to the affected side (Curthoys & Manzari, 2017; McGarvie et al., 2015; Zalewski, 2015). However, this can be hard to implement in older adults who may have neck or bone density problems, or who may not tolerate such rigorous procedures.

Otolithic functions are commonly assessed using the Vestibular Evoked Myogenic Potentials (VEMP) test. The VEMP measures the elicited muscle responses (ocular or neck muscles) to air- or bone- conducted auditory stimuli (Rosengren, Govender, & Colebatch, 2011). The ocular VEMP (oVEMP) evaluates the function of the utricle and the superior vestibular nerve; the saccule and inferior vestibular nerve are evaluated using the cervical VEMP (cVEMP) (Kantner & Gürkov, 2012). The normal oVEMP response is a biphasic wave that starts with a negative peak (n1 or n10) with a latency of around 10 ms, and then a positive peak (p1 or p15) with a latency of around 15 ms (Kantner & Gürkov, 2012). On the other hand, the cVEMP response typically starts with a positive peak (p13 or P1) at around 13 ms, followed by a negative peak (n23 or N1) after a latency of around 23 ms (Papathanasiou, Murofushi, Akin, & Colebatch, 2014). Adding to the earlier-mentioned study findings by Agrawal et al (2012), a large-scale study (C. Li, Layman, Carey, & Agrawal, 2015) on adults aged 26 to 92 years old also confirmed significant age-related increase in latencies and decrease in amplitudes of both cVEMP and oVEMP. Compared with adults younger than 70 years old, those aged ≥ 70 years old and ≥ 80 years old had increased odds of absent cVEMP and oVEMP responses, respectively. A more recent meta-analysis of 16 studies, on VEMP latencies and ageing, corroborated that both cVEMP and oVEMP latencies increase with increasing age (Macambira, Carnaúba, Fernandes, Bueno, & Menezes, 2017). The VEMP latencies in the older adult group (ages > 55 years old), compared with the younger group (ages ≤ 40 years old), were increased by 2.32 ms (95% CI [0.55,

4.10]), 1.34 ms (95% CI [0.56, 2.11]), and 2.82 ms (95% CI [0.33, 5.30]) for n1 oVEMP, p13 cVEMP, and n23 cVEMP, respectively ($p < .05$ for all). The p1 oVEMP latency component was not computed due to the inadequate number of studies reporting on it (Macambira et al., 2017).

Despite the declines evident in the various components of the vestibular system with increasing age, age effects on the vestibular system alone cannot explain the presentation of dizziness, postural instability and falls in older adults (Sloane, Baloh, & Honrubia, 1989). Healthy older adults without vestibular dysfunction may exhibit poorer balance when compared with younger people (Pedalini, Cruz, Bittar, Lorenzi, & Grasel, 2009), but they can continue to lead a physically active, fall-free lifestyle. However, pathology to any parts of the vestibular system at any age can have a significant impact on physical function, independence, and quality of life.

2.1.3 Vestibular dysfunction and functional impact

Farrell and Rine (2014) studied the differences in symptoms and impact on daily activities experienced by 14 subjects with canal- and otolithic- dysfunctions. They reported that the symptoms experienced by subjects with canal dysfunction were mainly rotary ("spinning" and "tumbling"). Subjects with otolithic dysfunction reported mainly non-rotary (linear) symptoms ("tilting", "pulling", "floor falling away", "rocking to and fro" and "rocking back and forth"). Subjects with both canal- and otolithic dysfunctions reported both rotary and linear symptoms while most subjects with only otolithic dysfunction did not report any rotary symptoms. Subjects with otolithic dysfunction (regardless of canal function) reported greater dizziness-related handicap in their daily activities. Falls were also mainly reported by subjects with otolithic dysfunction, with none experienced by those with canal dysfunction only (Farrell & Rine, 2014).

Another study investigated the associations between vestibular functions, and the temporal and spatial parameters of gait in 113 healthy adults (Anson, Pineault, Bair, Studenski, & Agrawal, 2019). The mean age of the group was 72.2 years old (SD = 14.6). The regression analysis showed that a decrease in horizontal semicircular canal function (by 0.1) resulted in increased stride length (β = -0.04 m, p = .004), increased stance (β = 15.8 ms, $p < .003$) and swing (β = −68.4 ms, p =.009) durations, and a reduced cadence (β = -2.1 steps/minute, $p < .001$), after controlling

for age, gender, height, stride length (for cadence, and stance and swing durations), cadence (for stride length), and gait speed (in place of cadence and stride length). Utricular and saccular functions were not associated with performance on any gait parameters (Anson et al., 2019).

A large-scale study (Semenov, Bigelow, Xue, Lac, & Agrawal, 2016) found that vestibular function loss was linked to decreased cognitive function and led to increased difficulty in carrying out activities of daily living and falls in adults aged ≥ 60 years old. The study found that vestibular function mediated 14.3% of the association between age and cognitive function. On the other hand, cognitive function mediated 16.9% and 4.9% of the associations between vestibular function with activities of daily living and falls, respectively (Semenov et al., 2016).

2.2 Benign Paroxysmal Positional Vertigo

Benign Paroxysmal Positional Vertigo (BPPV) is one of the most common causes of peripheral vertigo. Benign Paroxysmal Positional Vertigo happens when otoconia dislodge from the utricular macula and travel into one or more of the semicircular canals. It is characterised by brief, intense vertigo brought on by a sudden change in head position. The vertigo is usually accompanied by a typical nystagmus, both of which generally last less than a minute. Common symptoms of BPPV include rotational vertigo, light-headedness, nausea, oscillopsia, increased sensitivity to head motions, feeling off balance and fear of falling (Parnes, Agrawal, & Atlas, 2003; von Brevern et al., 2007). The incidence of BPPV increases with increasing age. A large epidemiological study (with 1003 subjects) reported the incidence of BPPV to be 0.6% per year, with a one-year prevalence of 1.6% (von Brevern et al., 2007). The one-year BPPV prevalence in older adults (> 60 years old) was 3.4%, which was seven times higher than that of younger adults (18 – 39 years old) at 0.5% (von Brevern et al., 2007). Over 90% of 1542 subjects in a recent BPPV study were above 50 years old, with the majority in the age group of 71 to 80 years old (Chua, Re, & S, 2020). The prevalence of BPPV in women is twice as high as that in men (Al-Asadi & Al-Lami, 2015; Chua et al., 2020; Ciorba et al., 2019; Katsarkas, 1999; Moon et al., 2006; von Brevern et al., 2007).

Benign Paroxysmal Positional Vertigo in the posterior semicircular canal is the most common form of BPPV, followed by BPPV in the horizontal canal, while anterior canal BPPV is rare (Chua et al., 2020; Moon et al., 2006; Parnes et al.,

2003; Yacovino, Hain, & Gualtieri, 2009). In terms of laterality, BPPV in the right labyrinth is more prevalent than in the left labyrinth (Al-Asadi & Al-Lami, 2015; Chua et al., 2020; Ciorba et al., 2019; von Brevern, Seelig, Neuhauser, & Lempert, 2004). The majority (50% - 70%) of BPPV cases are classified as “primary or idiopathic”, hence there are no clear etiologies (Parnes et al., 2003). A review on secondary BPPV (Riga, Bibas, Xenellis, & Korres, 2011) found a wide range of prevalence (3% - 66%) across nine studies but noted a range between 3% to 25% from the two biggest studies (Caldas, Gananca, Gananca, Gananca, & Caovilla, 2009; Karlberg, Hall, Quickert, Hinson, & Halmagyi, 2000). The same review also reported head trauma, Meniere’s disease, vestibular neuritis, and idiopathic sensorineural hearing loss to be the commonest causes of secondary BPPV (Riga et al., 2011). In addition, migraine and inner ear surgery were also plausible causes of secondary BPPV (Parnes et al., 2003; Riga et al., 2011). Apart from age and the aforementioned conditions, BPPV is also associated with other comorbidities: hypertension (Al-Asadi & Al-Lami, 2015; Chua et al., 2020; von Brevern et al., 2007), hyperlipidaemia (von Brevern et al., 2007), migraine (von Brevern et al., 2007), stroke (von Brevern et al., 2007), osteopenia/osteoporosis (Vibert, Kompis, & Häusler, 2003), and chronic otitis media (Al-Asadi & Al-Lami, 2015).

2.2.1 Proposed pathomechanism for BPPV

Benign Paroxysmal Positional Vertigo can be classified into either “canalithiasis” or “cupulolithiasis” depending on the presentation during positional tests. In 1969, Schuknecht proposed “cupulolithiasis” as the mechanism for BPPV (Schuknecht, 1969) (see Figure 2.1). Cupulolithiasis describes the adherence of the dislodged otoconia to the cupula. This increases the weight of the cupula and causes inappropriate displacement with head position changes, resulting in vertigo and nystagmus. During the positional test, cupulolithiasis presents with an immediate onset of vertigo and nystagmus, both of which persist throughout the duration of the maintained head position. Hall et al (1979) proposed a second theory of “Canalithiasis”: dislodged otoconia that move freely in the long arm of the semicircular canal. Any change in the position of the canal, in relation to gravity, will result in the movement of the free-floating otoconia. The movement of the otoconia results in the displacement of the endolymph within the canal, deflecting the cupula, and triggering vertigo and nystagmus. There is some delay from the displacement of

endolymph to cupula deflection, hence the latency in response time. Canalithiasis presents differently from cupulolithiasis. During the positional test, there is usually a latency of up to 40 seconds until the onset of vertigo and nystagmus. The intensity of both nystagmus and vertigo increases then wanes off, usually within a minute. Parnes and McClure (1992) confirmed the presence of free-floating particles in the posterior semicircular canal while performing canal occlusion surgeries for intractable BPPV. Canalithiasis is a more common form of BPPV compared to cupulolithiasis. One study with 1033 BPPV cases reported 97.5% of the cases were diagnosed with canalithiasis while 2.5% had cupulolithiasis (Caldas et al., 2009).

2.2.2 Diagnosis

Benign Paroxysmal Positional Vertigo is typically diagnosed with a combination of relevant history and diagnostic manoeuvres (positional tests) (Parnes et al., 2003). People with BPPV often complain of a sudden onset of vertigo, brought on by a sudden change in head position. The recurrent vertigo is frequently associated with actions such as lying down or rolling over in bed, looking or reaching up, and bending or reaching down. The vertigo usually does not last for more than 30 seconds to a minute, but dizziness (non-vertiginous) and unsteadiness may be present for the rest of the time (S. H. Lee & Kim, 2010). Nausea and vomiting commonly accompany vertigo. With a sudden onset of vertigo, there may be loss of balance and falls, triggering fear of falling. As a result, some people may restrict their movements and activities in their bid to avoid vertigo and other unpleasant sensations. A detailed history taking regarding the dizzy episodes should provide some insights and clues as to whether BPPV could be a possible cause of the dizziness.

Positional tests are objective tests used to confirm and diagnose BPPV. Proper diagnosis should include the specification of the semicircular canal(s) involved and the pathomechanism (canalithiasis or cupulolithiasis) (von Brevern et al., 2015). Clinical features of positional nystagmus such as the latency, direction, duration, and time course are important diagnostic criteria (von Brevern et al., 2015). There are various positional tests available to test for BPPV in the vertical (posterior and anterior) and horizontal canals. As BPPV can occur in a single canal or multiple canals, and unilaterally or bilaterally, it is integral to perform positional tests for all vertical and horizontal canals in patients with positional vertigo. The use of Frenzel

goggles or infra-red videonystagmography can make visualisation and identification of nystagmus easier (Imai et al., 2017; von Brevern et al., 2015). Studies have also found benefits in repeating positional tests in people with positional vertigo but who had tested negative on initial positional tests (Evren, Demirbilek, Elbistanli, Kokturk, & Celik, 2017; Pollak, 2009).

2.2.2.1 Vertical canals (Posterior and Anterior)

For the vertical canals, the Dix-Hallpike test (Dix & Hallpike, 1952) is most utilised and is the gold standard test for posterior canal BPPV (Bhattacharyya et al., 2017). To perform the Dix-Hallpike (DHP) test, the examiner turns the patient's head 45 degrees to the side being tested and lowers the patient from long sitting to supine lying. In the provoking position, the examiner supports the patient's head with the neck in 20 degrees extension, and the tested ear down (Bhattacharyya et al., 2017). For example, to test the right vertical canals, the examiner performs a Right Dix-Hallpike test. The starting position is with the patient in long sitting and the head is turned 45 degrees to the right. The patient is then brought back and down onto the plinth such that the neck is slightly extended (about 20 degrees) with the overhanging head supported by the examiner. This action is usually performed fairly quickly to perturb the otoconia (if present) in the canal. However, it may be performed slower if the patient is very fearful or requires extra care (i.e., older adults who are frail or anyone with musculoskeletal issues). In this position, the examiner checks the patient for vertigo and nystagmus, noting any latency of onset, direction of the nystagmus, and the duration of nystagmus/vertigo. Upon returning the patient into long sitting, the examiner observes for a reversal of the nystagmus (Bhattacharyya et al., 2017; von Brevern et al., 2015). However, the Dix-Hallpike test should be used with caution in the patients with the following conditions: neck pain, limited mobility, severe anxiety, history of stroke, morbid obesity, and frailty (Whitney, Marchetti, & Morris, 2005). Humphriss et al (2003) recommended that (i) patients be screened for vertebrobasilar insufficiency before performing the Dix-Hallpike test; and (ii) the Dix-Hallpike test be contraindicated in the following conditions: history of neck surgery, recent neck injury, instability and structural deformities of the C1 and C2 vertebrae, severe rheumatoid arthritis, carotid sinus syncope, cervical myelopathy and radiculopathy, Arnold-Chiari malformation, and vascular dissection syndromes.

An alternative test is the Side-lying test. With the Side-lying test, the starting position is in short sitting (sitting over the edge of the bed) and the patient's head is turned 45 degrees away from the side to be tested (Cohen, 2004). For example, to test the right ear, the patient's head is turned 45 degrees to the left. The examiner stands in front and briskly lowers the patient on to right side-lying while supporting the head. In that position, the examiner monitors and observes for nystagmus and vertigo, as with the Dix-Hallpike test. A recent study investigated the efficacy of a modified Dix-Hallpike test which is used clinically (Jeon, Lee, Park, Oh, & Seo, 2019). The procedures were similar to the original test except that the patient lies down onto a pillow (10 cm dense foam pillow) placed under the shoulders. This modification results in a natural neck extension with the back of the head resting on the bed. The authors reported no significant diagnostic difference and an excellent inter-test reliability between the standard and modified Dix-Hallpike tests (Jeon et al., 2019). The sensitivity and specificity of the modified Dix-Hallpike test were 95.5% (95% CI [89.3, 100]) and 87.9% (95% CI [79.5, 96.3]), respectively.

The most common BPPV finding with a Dix-Hallpike test is posterior canalithiasis. A posterior canalithiasis will present with a latency in the onset of nystagmus and vertigo after the patient has been lowered into position (von Brevern et al., 2015). In the right Dix-Hallpike test, with a right posterior canalithiasis, the nystagmus has two directional components: torsional and vertical. The torsional component beats/rotates towards the dependent ear – hence, right torsion; and the vertical component beats towards the crown of the head – upbeating (Imai et al., 2017) (see Table 2.1). The nystagmus usually increases, then decreases in intensity and lasts less than one minute (Bhattacharyya et al., 2017; Imai et al., 2017; von Brevern et al., 2015). Upon getting the patient up, a left torsional downbeating nystagmus may be observed (von Brevern et al., 2015). It is important to note that repeated positional testing may result in fatigability of vertigo and nystagmus (von Brevern et al., 2015).

While the above-mentioned presentation is typical of the common variant with free floating otoconia in the long arm of the posterior canal, there exists another variant with free floating otoconia located in the short arm (non-ampullary arm) of the posterior canal termed "Apogeotropic posterior canalithiasis" (see Figure 2.1) (Vannucchi, Pecci, & Giannoni, 2012). When put in a provocation position (Dix-Hallpike or straight head hanging position), the movement of otoconia in the non-

ampullary arm of the posterior canal creates an ampullopetal endolymphatic flow (inhibitory) in the posterior canal. Hence in a right Dix-Hallpike test, a right apogeotropic posterior canalithiasis presents with a left torsional and downbeating nystagmus (Vannucchi et al., 2012). There is little or no latency and the duration of nystagmus may last for more than one minute (Vannucchi et al., 2012; Vannucchi et al., 2015). The nystagmus is of low intensity (compared to the more common posterior canalithiasis), and the vertical component is more prevailing than the torsional component (Vannucchi et al., 2015). On sitting up from the provocation position, reversal of nystagmus is rarely seen but occurs with stronger intensity when it does happen (Helminski, 2019; Vannucchi et al., 2015). The sensation of vertigo is usually stronger on sitting up than on lying down (Vannucchi et al., 2015).

Posterior cupulolithiasis yields an upbeating nystagmus with torsion towards the affected ear as well (von Brevern et al., 2015). Hence, a right posterior cupulolithiasis presents with a right torsional upbeating nystagmus (see Table 2.1). However, the onset of nystagmus and vertigo is typically immediate, and the duration lasts more than one minute (more persistent compared with canalithiasis) (Imai et al., 2017; S. H. Lee & Kim, 2010; von Brevern et al., 2015). Anterior canalithiasis is uncommon; it made up 3% of the total number of BPPV cases (*N* = 9935) in a recent systematic review (Anagnostou, Kouzi, & Spengos, 2015).

Anterior canalithiasis can be diagnosed with the Dix-Hallpike, Side-lying or Straight-head hanging manoeuvres (Anagnostou et al., 2015; A. P. Casani, Cerchiai, Dallan, & Sellari-Franceschini, 2011). The nystagmus triggered is typically downbeating and torsional to the affected side. Unlike for posterior canalithiasis, the Dix-Hallpike test places both anterior canals in the provoking position, not just the dependent side. Therefore, the determination of the affected side in anterior canalithiasis is dependent on the torsional direction of the nystagmus (von Brevern et al., 2015) (see Table 2.1). One caveat is that identification of the affected side is not always probable as the nystagmus, in anterior canalithiasis, may not always have a torsional component, or the torsional component can be easily missed (Bertholon, Bronstein, Davies, Rudge, & Thilo, 2002; A. P. Casani, Cerchiai, et al., 2011). The use of Frenzel goggles or infra-red videonystagmography may help to better visualise the nystagmus. In the absence of torsion, it is pertinent to first rule out central nervous system (CNS) signs or lesions before confirming the BPPV diagnosis. Another indication of a correct diagnosis of anterior canalithiasis, in the

absence of any CNS lesion, will be the resolution of vertigo and nystagmus after repositioning manoeuvres (von Brevern et al., 2015). As both anterior canalithiasis and the contralateral apogeotropic posterior canalithiasis have similar presentations, it is important to know their differential characteristics. The anterior canalithiasis may be provoked by both left and right Dix-Hallpike tests but is always provoked in the straight head hanging position (Helminski, 2019). The apogeotropic posterior canalithiasis is provoked in either one or both Dix-Hallpike positions and sometimes in the straight head hanging position. The torsional component is stronger in apogeotropic posterior canalithiasis than in anterior canalithiasis (Helminski, 2019).

Table 2.1 Right Dix-Hallpike test: Possible BPPV signs and diagnoses

Diagnosis	Direction of nystagmus	Latency of nystagmus	Duration of nystagmus
Right Posterior Canalithiasis	*Right torsional, upbeating (Imai et al., 2017)	1 – 5 seconds (Parnes et al., 2003); 5 – 20 seconds (Bhattacharyya et al., 2017); May be ≤ 1 minute (Baloh, Honrubia, & Jacobson, 1987)	< 1 min (Bhattacharyya et al., 2017; Imai et al., 2017; von Brevern et al., 2015)
Right Posterior Apogeotropic Canalithiasis	^Left torsional downbeating; downbeating without torsion also possible (Helminski, 2019; Vannucchi et al., 2015)	Very brief latency or no latency (Vannucchi et al., 2012; Vannucchi et al., 2015)	≥ 1 min (Vannucchi et al., 2012; Vannucchi et al., 2015)

Diagnosis	Direction of nystagmus	Latency of nystagmus	Duration of nystagmus
Right Posterior Cupulolithiasis	*Right torsional upbeating (von Brevern et al., 2015)	No latency or brief latency (shorter than canalithiasis) (Imai et al., 2017; S. H. Lee & Kim, 2010; von Brevern et al., 2015)	> 1 min (von Brevern et al., 2015); more persistent than canalithiasis (Imai et al., 2017; S. H. Lee & Kim, 2010)
#Right Anterior Canalithiasis	Downbeating +/- right torsion	No latency to few seconds (A. P. Casani, Cerchiai, et al., 2011)	< 1 min (Bertholon et al., 2002); Few secs to > 1 min (A. P. Casani, Cerchiai, et al., 2011)
#Left Anterior Canalithiasis	Downbeating +/- left torsion	No latency to few secs (A. P. Casani, Cerchiai, et al., 2011)	< 1 min (Bertholon et al., 2002); Few secs to > 1 min (A. P. Casani, Cerchiai, et al., 2011)

Note: *Based on the above, the direction of the nystagmus torsional component for positive left posterior canalithiasis and cupulolithiasis on left Dix-Hallpike tests will be left torsional while the nystagmus vertical and time components remain unchanged for the respective diagnoses; ^The direction of the nystagmus torsional component for left apogeotropic posterior canalithiasis on left Dix-Hallpike test will be right torsional (if present) while the vertical component remains as downbeating; #Presentation remains unchanged regardless of laterality of Dix-Hallpike tests.

2.2.2.2 Horizontal canals

The Roll test (Pagnini-Lempert or Pagnini-McClure Roll Test) is predominantly used to assess for horizontal canal BPPV (Lempert & Tiel-Wilck, 1996; McClure, 1985). The patient lies supine with the head supported and flexed at 30 degrees to align the horizontal canals with gravitational pull (Cakir et al., 2006). The examiner briskly turns the patient's head to the side being tested and monitors for nystagmus and vertigo. The patient's head is returned to neutral once both vertigo and nystagmus stop (if present). The test is then repeated on the opposite side. If the

patient has cervical spine problems or limited range, the test may be conducted by getting the patient to roll into side-lying (instead of pure cervical spine rotation). Unlike BPPV of the vertical canals which tends to present with unilateral signs and symptoms, horizontal canal BPPV typically produces signs and symptoms with roll tests on both sides. For horizontal canalithiasis, the nystagmus produced is horizontal, beating towards the dependent head or earth: hence, left beating on left Roll test and right beating on right Roll test. This is termed as “geotropic” (McClure, 1985). There is brief latency to the onset of nystagmus and vertigo, the waxing and waning of intensities, and the duration typically lasting not more than one minute. The affected side is usually the one with more intense nystagmus and vertigo (see Table 2.2) (Imai et al., 2017; von Brevern et al., 2015). Horizontal cupulolithiasis, on the other hand, produces “ageotropic” nystagmus. That is nystagmus that beats away from earth; right-beating nystagmus and left-beating nystagmus with left roll and right roll tests, respectively. There is no latency to the onset of nystagmus and vertigo, and the responses are persistent (> 1 minute). The affected side, in horizontal cupulolithiasis, is the less symptomatic side (Imai et al., 2017; von Brevern et al., 2015). It is also important to note that movement of free-floating otoconia located near the ampulla in the horizontal canal produces ageotropic nystagmus. With repeated testing, the nystagmus may change direction to geotropic in such cases while a persistent ageotropic nystagmus confirms a cupulolithiasis diagnosis (A. P. Casani, Vannucci, Fattori, & Berrettini, 2002; von Brevern et al., 2015).

Table 2.2 Horizontal canalithiasis and cupulolithiasis: Characteristics of nystagmus with the Roll test

Diagnosis	Direction of nystagmus	Latency of nystagmus	Duration of nystagmus	Affected side
Horizontal Canalithiasis	Geotropic (towards gravity) (Imai et al., 2017; von Brevern et al., 2015)	Very short latency; a few seconds (A. P. Casani et al., 2002; Imai et al., 2017; von Brevern et al., 2015)	< 1 min (Imai et al., 2017; von Brevern et al., 2015)	More symptomatic side (von Brevern et al., 2015)
Horizontal Cupulolithiasis	Ageotropic (against gravity) (Imai et al., 2017; von Brevern et al., 2015)	No latency or very brief latency (A. P. Casani et al., 2002; Imai et al., 2017; von Brevern et al., 2015)	> 1 min (Imai et al., 2017; von Brevern et al., 2015); No or poor fatigability (A. P. Casani et al., 2002)	Less symptomatic side (von Brevern et al., 2015)

It may be difficult to determine the affected side with supine roll tests at times. This is especially so when the difference in intensities on both sides are less discerning. In such cases, the Bow and Lean test, the sit to supine test, or the supine to sit test can be used to further confirm which is the affected ear (see Table 2.3). The Bow and lean test is performed with the patient, bowing the head forward (past 90°) and bringing the head back 45°, in sitting (Choung, Shin, Kahng, Park, & Choi, 2006). The sit to supine test (lying-down nystagmus) is done by getting the patient to lie back down (supine) from a long sitting position while looking straight ahead (Koo,

Moon, Shim, Moon, & Kim, 2006; S. H. Lee et al., 2007). For the supine to sit test (head-bending nystagmus), the patient is moved straight up from supine to long sit, and the head bends forward (S. H. Lee et al., 2007).

Table 2.3 Additional confirmatory tests to decide on the affected side in horizontal canal canalithiasis and cupulolithiasis

Test	Geotropic nystagmus (Canalithiasis)	Ageotropic nystagmus (Cupulolithiasis)
Bow and lean (Choung et al., 2006)	*Bow*: beats towards affected side *Lean*: beats away from affected side	*Bow*: beats away from affected side *Lean*: beats towards affected side
Sit to supine (lying-down nystagmus) (Choung et al., 2006; Koo et al., 2006; S. H. Lee et al., 2007)	Beats away from affected side	Beats towards affected side
Supine to sit (head-bending nystagmus) (S. H. Lee et al., 2007)	Beats towards affected side	Beats away from affected side

2.2.3 Management

The gold standard treatment for BPPV is a group of physical procedures known as “repositioning manoeuvres”. Repositioning manoeuvres are generally treatment performed on patients with BPPV by either the doctors, physiotherapists, or vestibular therapists. There are different manoeuvres meant for the different semicircular canals and pathomechanism (canalithiasis/cupulolithiasis). The main aim of repositioning manoeuvres is to move the otoconia out of the semicircular canal and back to the vestibule through a series of head manoeuvres or positions (Pérez-Vázquez & Franco-Gutiérrez, 2017). Anti-vertigo and anti-emetic medications are often prescribed by doctors to help alleviate the unpleasant symptoms. Evidence has well shown that these medications, compared with repositioning manoeuvres, are less efficacious in resolving BPPV (Bhattacharyya et al., 2017; T. D. Fife et al.,

2008; Kaur & Shamanna, 2017). Routine use of vestibular suppressants in BPPV is also discouraged (Bhattacharyya et al., 2017). Patients with BPPV may also be prescribed with Brandt-Daroff and Vestibular Rehabilitation exercises to further alleviate symptoms and improve gaze stability and balance (Bhattacharyya et al., 2017; Pérez-Vázquez & Franco-Gutiérrez, 2017). Surgical intervention for BPPV is extremely rare and are usually performed for patients with intractable BPPV not amenable to the above-mentioned treatments (Bhattacharyya et al., 2017; T. D. Fife et al., 2008; Parnes et al., 2003).

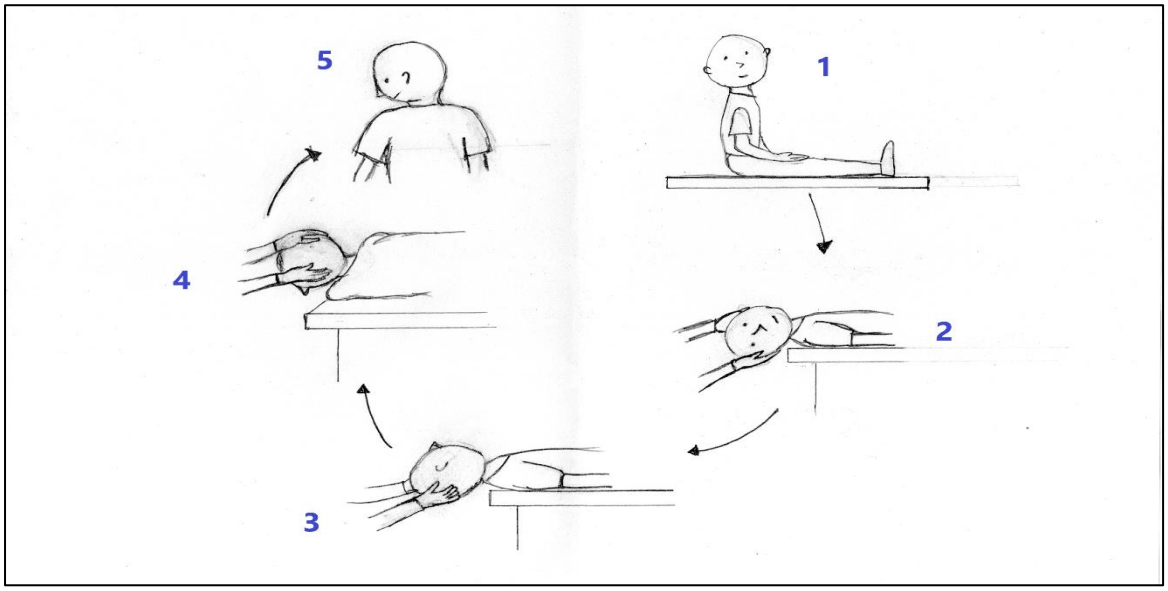
2.2.3.1 Repositioning manoeuvres

The Epley manoeuvre, also known as the “Canalith Repositioning Procedure or Manoeuvre (CRP/CRM)”, is a well-researched and an established treatment for posterior canalithiasis (Bhattacharyya et al., 2017; T. D. Fife et al., 2008; Herdman & Hoder, 2014). The starting positions are the same as the Dix-Hallpike test for the affected side. The treatment advances through various positions to move the otoconia, along the arm of the posterior semicircular canal, back into the vestibule (see Figure 2.2). Each of these positions is maintained for some time, to allow for the nystagmus and vertigo to settle, before moving onto the next position. The duration of stay in each position varies according to different authors: (i) 20 to 30 seconds (Bhattacharyya et al., 2017; T. D. Fife et al., 2008); (ii) 1 to 2 min (Parnes et al., 2003); and (iii) until nystagmus stops or for twice the duration of the nystagmus (Herdman & Hoder, 2014). The Epley manoeuvre may also be used to treat anterior canalithiasis (Herdman & Hoder, 2014).

Natural recovery is possible in BPPV in 20% to 80% of the cases but the time taken may take weeks to months (Salvinelli et al., 2004; Sekine, Imai, Sato, Ito, & Takeda, 2006; Seo, Miyamoto, Saka, Shimano, & Sakagami, 2007). The efficacy of the Epley manoeuvre could be as high as over 90% in just one or two treatment sessions (Babac & Arsovic, 2012; Prokopakis et al., 2013; Richard, Bruintjes, Oostenbrink, & Leeuwen, 2005) and could reach 100% in four to five treatment sessions (Reinink, Wegner, Stegeman, & Grolman, 2014). One recent study (Sachdeva & Sao, 2020) investigated the clinical response time of the Epley manoeuvre in 130 subjects, aged 30 to 50 years old, who were diagnosed with posterior canalithiasis. While 37% of subjects were fully well after a single treatment session, 42% required up to four sessions (15 days to a month) and 20% needed

more than four sessions (up to six months) (Sachdeva & Sao, 2020). Several systematic reviews and meta-analyses concluded that the Epley manoeuvre is more superior in alleviating symptoms and conversion to negative positional test outcomes, compared to no treatment and sham procedures (Hilton & Pinder, 2014; Prim-Espada, De Diego-Sastre, & Perez-Fernandez, 2010; Rodrigues, Ledesma, de Oliveira, & Bahamad Junior, 2018; Teixeira & Machado, 2006; Woodworth, Gillespie, & Lambert, 2004). One meta-analysis found that subjects treated with CRT (Epley manoeuvre), compared with controls, were 4.6 and 5.2 times more likely to achieve symptom resolution and a negative positional test, respectively at first follow-up (Woodworth et al., 2004). Another reported subjects who underwent Epley manoeuvre were 6.5 times more likely to experience improvement in their clinical symptoms compared with controls (Prim-Espada et al., 2010). The likelihood of a conversion to negative Dix-Hallpike test was also five times more in subjects treated with Epley manoeuvre, compared to those who did not undergo this procedure.

Figure 2.2 Epley manoeuvre for the treatment of right posterior canalithiasis



Note. The patient starts with his head turned 45 degrees to the right in long sitting (Position 1). He is then brought back and down onto his back with the overhanging head supported (Position 2). The head is then rotated 90 degrees to the opposite side (or 45 degrees to the left; Position 3). The patient turns on his left side with the head turned 45 degrees down towards the floor (Position 4). Finally, the patient sits up from his unaffected side, with his head maintained in the previous posture (Position 5). Adapted from "Epley maneuver: A simple treatment for a common cause of vertigo", In MSD Manual Professional Version, accessed on 8 March 2021 (https://www.msdmanuals.com/professional/multimedia/figure/ent_epley_maneuver) (MSD Manual Professional Version, 2021). Copyright 2021 Merck Sharp & Dohme Corp.

A recent RCT investigated a modified version of the Modified Epley manoeuvre performed with a pillow placed under the shoulders (H. J. Lee, Jeon, Lee, & Seo, 2020). The procedures were performed exactly as the standard Modified Epley but with a 10 cm thick dense foam pillow under the shoulders. This modification allowed the necessary neck extension (20 – 30 degrees) while the head was supported on the bed. This enabled the examiner to better focus on guiding the head movements and monitor the subjects. Forty-one subjects with posterior canalithiasis (mean age 54.1±10.4 years old) were randomly allocated into either the standard Modified Epley group (n = 21) or the modified version with a pillow under the shoulders (n = 20). The subjects were evaluated seven days after the treatment. The success rates were similar (Standard Modified Epley group - 85.7%; Modified Epley with pillow under the shoulders group - 80.0%) with no significant difference between the two groups (p = .697) (H. J. Lee et al., 2020).

The Semont manoeuvre, also known as the Semont Liberatory manoeuvre, is another procedure used to treat BPPV of the posterior semicircular canal (Bhattacharyya et al., 2017; Herdman & Hoder, 2014). This technique involves rapidly performed movements between positions to dislodge the otoconia adhering to the cupula (cupulolithiasis) and reposition the free-floating ones (canalithiasis) back into the vestibule (Bhattacharyya et al., 2017; Herdman & Hoder, 2014). The treatment starts with the patient in short sitting and the therapist standing in front of the patient. The patient's head is turned 45 degrees away from the affected side and this position is maintained throughout the repositioning. The therapist briskly moves the patient sideways onto the affected side. This position is maintained until the nystagmus settles (~ one minute). The therapist then swiftly moves the patient through 180 degrees arc onto the opposite side. Once the nystagmus/vertigo subsides (~ one minute), the patient is slowly brought back to the sitting position (T. D. Fife et al., 2008; Herdman & Hoder, 2014). It is postulated that the Semont manoeuvre could be used to treat anterior cupulolithiasis as well (Herdman & Hoder, 2014) but there has been no eye recording evidence of anterior cupulolithiasis (von Brevern et al., 2015). Hilton and Pinder (2014), in their systematic review, found the efficacies of both Epley- and Semont- manoeuvres to be comparable in treating BPPV of the posterior canal. A recent meta-analysis compared the efficacy of the Semont manoeuvre with other treatment options (Zhang et al., 2017). The Semont manoeuvre yielded better recovery rate compared with sham (RR = 4.89, 95% CI

[3.01, 7.94], $p < .01$) or no treatment (RR = 2.60, 95% CI [1.97, 3.44], $p < .01$). There was no difference in recovery rates between Semont manoeuvre and Epley manoeuvre (RR = 0.83, 95% CI [0.68, 1.00], $p = .05$), as well as, Brandt-Daroff exercise (RR = 1.32, 95% CI [1.00, 1.75], $p = .05$). Rodrigues et al (2018), in their systematic review of treatment for BPPV (mainly of Epley and Semont manoeuvres), reported the short- and long-term efficacies of 84.7% and 89.2%, respectively; and the recurrence rates ranged from 6% to 36%.

The Li repositioning manoevures were also proposed for the treatment of BPPV of the posterior-, anterior-, and horizontal- canals (J. Li & Li, 2010). For the treatment of posterior canalithiasis, the patient starts in short sitting with the head forward and is quickly brought into side-lying on the affected side (J. Li & Li, 2010; J. Li, Tian, & Zou, 2017). The patient stays in this position for a minute or until the nystagmus and vertigo stop. The therapist, standing behind the patient's thighs and facing the patient, supports the head. The patient is then brought into side-lying onto the unaffected side in one swift action (~ 1 sec). This position is maintained for four minutes before the patient is brought swiftly up to sitting (J. Li & Li, 2010; J. Li et al., 2017). A randomised trial, with a sample of 113 participants diagnosed with posterior canal BPPV, found no significant differences in the short-term efficacies (three days and one week post repositioning) between the Li- and Epley- manoeuvres. The Li manoeuvre for the anterior canal BPPV does not depend on the side of lesion. The patient starts in a supine position with the legs hanging over the sides of the bed. The therapist stands next to the patient, with one hand under the occiput and another over the forehead. The therapist brings the patient from supine to sitting and to prone as quickly as possible. The patient stays prone for four minutes (J. Li & Li, 2010). To date, there has been no study done on the Li manoeuvre for anterior canal BPPV.

Vannuchi et al (2015) proposed two treatment techniques for apogeotropic posterior canalithiasis: the Demi Semont manoeuvre and the 45° Forced Prolonged Position (45° FPP). According to the authors, if these techniques are effective or converts the apogeotropic posterior canalithiasis to (geotropic) posterior canalithiasis, then the diagnosis of apogeotropic posterior canalithiasis can be confirmed (as opposed to contralateral anterior canalithiasis). Another novel repositioning manoeuvre was proposed recently for the treatment of torsional-vertical downbeating positioning nystagmus (Garaycochea, Pérez-Fernández, & Manrique-

Huarte, 2020). This treatment requires a clear identification of the side of lesion but with a possible diagnosis of either ipsilateral anterior canalithiasis or contralateral apogeotropic posterior canalithiasis. The procedure starts with the patient in sitting with the head flexed forward at 45 degrees. The patient slowly rotates the head towards the unaffected side (in relation to the diagnosed laterality of anterior canalithiasis). Next, the patient quickly bends forward 90 degrees at the lumbar spine/hips, bringing the head to the level of the knees. After one minute, the patient rotates his head towards the affected side while staying bent forward. He stays in that position for another minute before quickly returning to upright sitting. In upright sitting, the patient slowly rotates the head back to midline, and bring the head up into neutral position to complete the procedure. The authors proposed that the repositioning treatment was designed to move the otoconia into the common crus for anterior canalithiasis; or in the case of contralateral apogeotropic posterior canalithiasis, move the otoconia from the non-ampullary arm to the ampullary arm of the posterior canal (Garaycochea et al., 2020).

Apart from the Epley manoeuvre, the Reverse Epley manoeuvre was also proposed for the treatment of anterior canalithiasis (Honrubia, Baloh, Harris, & Jacobson, 1999; Seok et al., 2008). The Reverse Epley manoeuvre refers to the Epley manoeuvre meant to treat the contralateral posterior canalithiasis (Epley, 2006). Both Epley and Reverse Epley manoeuvres require the affected side to be diagnosed so that the correct treatment can be applied. Another treatment for anterior canalithiasis is the Deep head hanging manoeuvre, which does not require a known affected side (Yacovino et al., 2009). The patient, in long sitting, is brought straight back into supine with the head hanging at least 30 degrees below the horizontal. This position is maintained for 30 seconds or until the nystagmus and vertigo subside. The head is then positioned in forward flexion (chin to chest) and maintained for 30 seconds or until the nystagmus and vertigo stop; and ends with the patient sitting up, and the head still flexed (Yacovino et al., 2009). A systematic review, on anterior canal BPPV, reported sample-size-weighted mean success rates of 83.3%, 91.5%, and 82.9% for Epley, Reverse Epley and pooled results from non-lateralising manoeuvres (Deep head hanging included), respectively. However, it is not possible to compare and conclude on the efficacies of these repositioning treatments on anterior canal BPPV given the dearth of robust studies in this area (Anagnostou et al., 2015; Pérez-Vázquez & Franco-Gutiérrez, 2017).

For horizontal canalithiasis, there are several treatment options: The Bar-B-Que Roll, the Gufoni manoeuvre (for the geotropic variant of the horizontal canal BPPV), the Forced Prolonged Position (FPP), and the Li manoeuvre. The Bar-B-Que Roll, also known as the Lempert manoeuvre, was adapted, and modified from the Epley manoeuvre (Lempert & Tiel-Wilck, 1996). The manoeuvre starts with the patient in supine and moved in 90 degrees increment towards the unaffected ear, rotating along the longitudinal axis of the head in supine. Each position is maintained for 30 to 60 seconds, until the nystagmus and vertigo are settled. One variation was completing the manoeuvre in 270 degrees and the patient gets up from the affected side (Lempert & Tiel-Wilck, 1996). Another version was a 360-degrees manoeuvre, and the patient ends in the supine position (Baloh, Furman, Halmagyi, & Allum, 1995). Tirelli and Russolo (2004) proposed two modifications to the roll manoeuvre: (i) The manoeuvre starts with the affected side – patient's head or entire body rotated to the affected side; and (ii) the head is positioned in 30 degrees flexion in supine (after starting position). For the Gufoni manoeuvre (or Liberatory manoeuvre for the horizontal canalithiasis (Appiani, Catania, & Gagliardi, 2001) or Appiani manoeuvre (Herdman & Hoder, 2014)), the patient sits over the edge of the bed and is quickly brought into side-lying on the unaffected side, remaining in that position for one minute after the nystagmus and vertigo have stopped. The patient's head is then quickly rotated 45 degrees down and the position is maintained for two minutes, before being returned to sitting gradually (Appiani et al., 2001). The Forced Prolonged Positioning (FPP) requires the patient to lie on the unaffected side for about 12 hours (Vannucchi, Giannoni, & Pagnini, 1997). The patient is instructed to go to bed and first lie on the affected side for 30 to 60 seconds, then slowly roll over onto the unaffected side and stay in that position for the night (8 – 12 hours) (Herdman & Hoder, 2014). This technique uses gravity to settle the free-floating otoconia, in the posterior arm of the horizontal canal, back into the vestibule (Vannucchi, Asprella Libonati, & Gufoni, 2005) and can be used with other manoeuvres (A. P. Casani, Nacci, et al., 2011; Herdman & Hoder, 2014).

The Li manoeuvre starts with the patient in supine, followed by rolling into side-lying on the affected side (J. Li & Li, 2010; Jinrang Li, Zou, & Tian, 2018). The side-lying position is maintained until the symptoms subside. The therapist stands behind the patient and quickly rolls the patient into side-lying on the unaffected side by grabbing the patient's lower hand (180 degrees roll). This position is maintained

for two to four minutes before the patient is brought into sitting (J. Li & Li, 2010; Jinrang Li et al., 2018). The Li manoeuvre for horizontal canalithiasis was found to be equally effective when compared with the Barbeque roll (Jinrang Li et al., 2018) and the Gufoni manoeuvre (Zhao, Li, Ding, Wang, & Zou, 2021).

Cupulolithiasis is less common compared with canalithiasis; it made up 26 - 30% of the total number of horizontal canal BPPV cases (Cakir et al., 2006; Maranhao & Maranhao Filho, 2015). Casani et al (2002) proposed a treatment for horizontal cupulolithiasis, known as the “Casani manoeuvre”. The patient is brought quickly into side-lying on the affected side, followed by quick head rotation 45 degrees down facing the plinth. This position is then maintained for two to three minutes before the patient is returned to sitting briskly (A. P. Casani et al., 2002). The Gufoni maneouvre has another version for the cupulolithiasis variant (Appiani, Catania, Gagliardi, & Cuiuli, 2005). The patient is brought into side-lying and stays there for one minute after the nystagmus and vertigo have settled; followed by turning the head 45 degrees up and staying for another two minutes before bringing the patient back to sitting slowly (Appiani et al., 2005). The Forced Prolonged Positioning (FPP) can also be performed for horizontal cupulolithiasis by lying on the affected side for around 12 hours (Vannucchi et al., 2005).

Kim et al (2012) reported a repositioning manoeuvre for horizontal cupulolithiasis – the Cupulolith Repositioning Manoeuvre (CuRM). The patient starts in supine, and each change in position is maintained for three minutes. The patient’s head is turned 135 degrees to the side of lesion. In this position, a hand-held vibrator is used to deliver vibrations to the suprameatal triangle of the lesioned ear for 30 seconds. The head is then rolled 45 degrees towards the unaffected side such that the patient is side-lying on the affected side. Next, the patient’s head is rolled 90 degrees towards the unaffected side, hence returning to the supine position. The patient’s head is rolled 90 degrees towards the unaffected side again – the patient will then be side-lying on the unaffected side. Here, vibrations are delivered to the suprameatal triangle of the affected ear again. The final move is to rotate the patient’s head another 90 degrees towards the unaffected side ending in a prone position, followed by sitting up without extension of the neck. The cure rate in their sample of 78 patients was 97.4% with an average of 2.1 manoeuvres (S. H. Kim et al., 2012). Another treatment technique published was the Zuma manoeuvre (Zuma e Maia, 2016). The patient starts sitting over the edge of the bed, and briskly lies

down on the affected side (side-lying). After three minutes, the head is turned 90 degrees to the unaffected side and the patient lies supine for another three minutes. Next, the head is quickly turned another 90 degrees to the unaffected side and maintained for three minutes. The head is then tilted forward slightly, followed by a return to sitting upright with the head back to midline.

Horizontal canal BPPV is known to have good natural recovery. The reported spontaneous recovery rates at one month follow-up ranged from 48% to 93% (A. P. Casani, Nacci, et al., 2011; A. P. Casani et al., 2002; Nuti, Agus, Barbieri, & Passali, 1998; Sekine et al., 2006). Imai et al (2005) reported the average onset-to-remission time for horizontal canalithiasis was 16 days (*SD* = 19), compared with 39 days (*SD* = 47) for posterior canalithiasis. However, in view of the intense symptoms and postural stability issues faced by patients with BPPV, it is still more beneficial for patients to receive early treatment to hasten recovery (Kinne, Strace, & Crouch, 2012). Of the above discussed treatments for horizontal canal BPPV, only the Gufoni manoeuvre (for both geotropic and ageotropic variants) has enough evidence to support its efficacy against sham or no treatment (El-Makhzangy, 2015; van den Broek, van der Zaag-Loonen, & Bruintjes, 2014). A meta-analysis reported an odds ratio of 0.15 (CI [0.04, 0.50], p = .002) for the Gufoni manoeuvre against sham manoeuvre in resolving nystagmus and vertigo in subjects with horizontal canal BPPV (El-Makhzangy, 2015). However, the Gufoni manoeuvre was reported to be more efficacious in treating horizontal canalithiasis and less so for cupulolithiasis (Riga, Korres, Korres, & Danielides, 2013; Vannucchi et al., 2005). Studies found the Gufoni manoeuvre relatively easy to administer, compared with the roll manoeuvres, especially for patients who are older or obese; have musculoskeletal, cervical spine or mobility problems (El-Makhzangy, 2015; Oron, Cohen-Atsmoni, Len, & Roth, 2015; van den Broek et al., 2014). The Gufoni manoeuvre was compared with the combined treatment, of the Barbecue (Roll) manoeuvre and the Forced Prolonged Positioning (Roll + FPP), in a randomised controlled trial (RCT) (A. P. Casani, Nacci, et al., 2011). The Gufoni manoeuvre yielded significantly better success rates (86%, 90%, and 93%) when compared with treatment of Roll + FPP (61%, 70%, and 80%) over the first three treatment sessions, respectively (p < .05). But the treatment results did not differ at one-month follow-up (Gufoni 93% vs BBQ + FPP 81%, p = .063), but both treatments were still better than vestibular suppressants (60% symptom-free at one month) (A. P. Casani, Nacci, et al., 2011). Another RCT

compared the Gufoni manoeuvre, the Barbecue (Roll) manoeuvre, and a Sham manoeuvre (J. S. Kim et al., 2012). Both Gufoni and Roll manoeuvres produced significantly better results than the Sham manoeuvre at both short term (after one and two repositioning manoeuvres) and long term (one month later). But the Gufoni and Roll manoeuvres did not differ in their results over all time points (J. S. Kim et al., 2012). A RCT comparing the Roll manoeuvre and no treatment found no significant difference in the recovery rates: at one week – 79% vs 69%; and at one month – 95% vs 93%, respectively (p = .375) (Sekine et al., 2006). Other non-RCT studies reported initial success rates between 38% and 74% for the Roll manoeuvre (Escher, Ruffieux, & Maire, 2007; Korres, Riga, Xenellis, Korres, & Danielides, 2011; Nuti et al., 1998). For Forced Prolonged Positioning (FPP) and the Casani manoeuvre, there have been no RCT to date. The success rates for FPP ranged from 75% to 90% (Appiani et al., 2005; A. P. Casani et al., 2002; Chiou, Lee, Tsai, Yu, & Lee, 2005; Vannucchi et al., 1997) while that of the Casani manoeuvre was around 75% (A. P. Casani et al., 2002; Korres et al., 2011).

2.2.3.2 Post manoeuvre restrictions and use of mastoid vibration

Post manoeuvre advice given to patients may include postural restrictions such as avoiding sleeping on the affected side, to sleep in an elevated position (not flat), and avoiding sudden, rapid head movements (Devaiah & Andreoli, 2010; Herdman & Hoder, 2014; Hunt, Zimmermann, & Hilton, 2012). A meta-analysis by Devaiah and Andreali (2010) found no added advantage of post manoeuvre postural restrictions to the efficacy of repositioning manoeuvres}. Another meta-analysis reported a small effect size of these postural restrictions added to Epley manoeuvre over Epley alone (RR 1.13, 95% CI [1.05, 1.22], p = .002) (Hunt et al., 2012). Overall, there is inadequate evidence to support the use of post manoeuvre postural restrictions; but clinicians should be aware that as the studies had omitted subgroups of patients (exclusion criteria), there may be patients who will benefit from post manoeuvre postural restrictions (Bhattacharyya et al., 2017). The use of mastoid vibration during the Epley manoeuvre was to prevent the otoconia from sticking to the canal walls and to improve their transportation along the canal (Herdman & Hoder, 2014). A meta-analysis by Hunt et al (2012) found no significant improvement to the efficacy of the Epley manoeuvre when mastoid vibration was added to the procedure (RR 1.02, 95% CI [0.89, 1.17], p = .79).

2.2.3.3 Vestibular rehabilitation

According to the American Academy of Otolaryngology – Head and Neck Surgery Foundation Clinical Practice Guideline for BPPV (Bhattacharyya et al., 2017), vestibular rehabilitation has been defined as “physical manoeuvres or exercise regimens to treat dizziness and balance disorders” (p28) but for the purpose of its function in BPPV management, it is further defined as “any additional therapy beyond isolated CRP for patients who fail initial CRP attempts, are not candidates for CRP, have additional impairments, and/or who refuse CRP” (p28). Vestibular rehabilitation includes a broad range of treatment: movement/habituation-based exercises (including the Brandt-Daroff exercise), gaze stabilisation exercises, balance exercises, gait and functional retraining, occupational retraining, and falls prevention. to name a few (Bhattacharyya et al., 2017).

The Brandt-Daroff exercise (BDE) was first introduced as a treatment for BPPV in 1980 (Brandt & Daroff, 1980). The BDE involved a series of repeated precipitating movements aimed at dislodging and dispersing the otoconia from the cupula of the posterior canal (Brandt & Daroff, 1980). The BDE is often prescribed as a home exercise for patients with BPPV. The patient starts in sitting with the head turned 45 degrees away from the affected side, then quickly goes into side-lying on the affected side. The patient returns to sitting, then turns the head 45 degrees to the affected side and lies down briskly onto the non-affected side. The patient then returns to sitting again. Each position is maintained for at least 30 seconds (after vertigo stops) (Brandt & Daroff, 1980; Herdman & Hoder, 2014). The exercise is repeated 10 to 20 times (per session), thrice a day, until the patient is asymptomatic for two consecutive days (Herdman & Hoder, 2014).

Van Der Scheer-Horst et al (2014), in their systematic review of two studies, found that there was no added benefit of vestibular rehabilitation to the Epley manoeuvre in adults aged 21 to 85 years old. Wegner et al (2014) concluded that the Epley manoeuvre was more effective than vestibular rehabilitation in the short term, however there was no difference between them in the long term. More recent systematic reviews (Bressi et al., 2017; Hillier & McDonnell, 2016) agreed with Wegner et al (2014). However, they also concluded that the combined therapy of repositioning manoeuvre and vestibular rehabilitation are of benefits for functional

recovery in the longer term, especially for the older adult population (Bressi et al., 2017; Hillier & McDonnell, 2016).

Section 2.2 discussed the etiology, hypothesised pathomechanisms, diagnosis, and management of BPPV. This condition is known to be more prevalent in people aged 50 years and more. The next section focuses specifically on BPPV in this important sub-group - older adults. The current evidence and gaps on BPPV and its management in older adults will also be discussed.

2.3 Older Adults and BPPV

It was mentioned earlier in this chapter (Section 2.2) that BPPV may affect people of all ages, but older adults are more susceptible to BPPV. A study using mice (Andrade, Lins, Farina, Kachar, & Thalmann, 2012) found demineralisation in the otoconia of two-year-old mice (equivalent to middle-aged humans). This resulted in weakened fibre connections between the otoconia, and otoconial dislodgement and release into the endolymph (Andrade et al., 2012). Walther et al (2013), using electron microscopy, provided further evidence of morphological changes and degeneration of the human utricular otoconia with age and the link to BPPV. A recent meta-analysis on the risk factors to BPPV occurrence found no significant age effects between the experimental and control groups (J. Chen, Zhao, Yue, & Zhang, 2020). However, it is noteworthy that the mean ages of the subjects from 10 (out of 13) studies were above 55 years old, and only one study had a mean age below 40 years old (J. Chen et al., 2020). The same study found the following risk factors to be significantly associated with BPPV occurrence: being female, high total cholesterol level, vitamin D deficiency, osteoporosis, migraine, and head trauma (J. Chen et al., 2020). Moreover, vitamin D deficiency, osteoporosis and high total cholesterol level are common with increasing age. The lack of physical activity in adults above 60 years of age was associated with a predisposition to BPPV (Pollak, Kushnir, & Goldberg, 2011). A separate study on older adults with BPPV discovered that older women with lower physical activity levels were more likely to have BPPV (Bazoni et al., 2014). There was no association between BPPV and the level of physical activity in older men (Bazoni et al., 2014).

The vertiginous attacks and postural disturbances brought about by BPPV further inflate the risks of falls in older adults. Vertigo was found to be the most common cause of falls in older adults with vestibular problems, and recurrent falls

led to activity restriction (Ganança et al., 2006). Often, older adults may actively avoid certain movements or positions, and even move slower, to prevent vertigo and falls. It was reported that older adults with BPPV tend to complain of postural instability and dizziness, instead of the classical vertiginous sensation (Batuecas-Caletrio et al., 2013; Plodpai et al., 2014). This could result in wrong or missed diagnoses and hence, delayed treatment for these patients. Oghalai et al (2000) discovered unrecognised BPPV in 9% of an older adult population, in which 61% had dizziness and 77% complained of poor balance. These older adults with unrecognised BPPV were also more likely to have reduced daily activity scores, depression, and had sustained a fall in the prior three months (Oghalai et al., 2000). Older adults with BPPV were found to experience more falls, compared to those without BPPV or those with other types of dizziness (Lawson et al., 2008; Oghalai et al., 2000).

2.3.1 Current evidence and gaps

2.3.1.1 Short-term and long-term efficacies of repositioning manouevres

Repositioning manoeuvres are current gold standard treatment for BPPV. The efficacies of various repositioning manoeuvres were presented earlier. However, evidence specific to the older adult population is conflicting. Some studies concluded that post repositioning manoeuvres, treatment success was similar for both younger and older adults with BPPV (Kao et al., 2009; Kasse et al., 2012; Yeo et al., 2018). In contrast, other studies reported that repositioning manoeuvres were less effective, including higher BPPV recurrences, in older adults (Babac et al., 2014; Batuecas-Caletrio et al., 2013). Yeo et al (2018) found no difference in recurrence rates between younger and older adults at both 1- and 5- years follow-ups while other studies concluded that older adults were more susceptible to BPPV recurrences (Batuecas-Caletrio et al., 2013; Kao et al., 2009; Korres, Balatsouras, & Ferekidis, 2006; Prokopakis et al., 2013). A recent systematic review of six studies by Ribeiro et al (2017) on repositioning manoeuvres in older adults with BPPV reported the treatment to be effective in this population. However, most studies had a follow-up period of four to 13 weeks. This underscores the need for more longer-term studies in this population.

2.3.1.2 Physical, functional, and subjective/self-reported outcomes

Oliva Dominguez et al (2005) investigated postural control of subjects with BPPV using the Sensory Organisation Test (SOT). They found that subjects with BPPV, across all ages, exhibited poorer postural control when compared with controls in the same age group. This difference was significantly greater in older subjects and was predominantly vestibular in origin (SOT Conditions 5 and 6) (Oliva Domínguez et al., 2005). Postural stability had been shown to improve following successful repositioning manoeuvres (Celebisoy, Polat, & Akyurekli, 2008) but the improvements were not always optimal (Di Girolamo et al., 1998; Stambolieva & Angov, 2006). Abou-Elew et al (2011) also investigated postural stability of subjects with BPPV, both before and one week after successful repositioning treatment, using the SOT. They found that postural stability was still not normalised in two-thirds of the subjects at one week post successful treatment, but this was not associated with age (Abou-Elew et al., 2011). Blatt et al (2000) also used the SOT to measure postural stability pre- and post- successful repositioning manoeuvres; they reported a significant age difference between subjects with improvement (*M* 54.3 years old, *SD* 9.2) and without improvement (*M* 63.0 years old, *SD* 13.7; $p < .05$) in postural stability (Blatt et al., 2000).

The efficacy of the repositioning manoeuvres, especially Epley manoeuvre, have been widely studied. The outcomes most frequently used to measure success in BPPV treatment are the positional test results (conversion from positive to negative test), subjective symptom rating (vertigo), and/or the Dizziness Handicap Inventory (DHI – which measures self-perceived handicap associated with dizziness). Patient-reported outcomes (measuring quality of life, symptoms, health perception, or physical function), balance, gait, and mental health (i.e., anxiety, depression) are less explored. Even when there are evidence, as in the example of postural control discussed earlier, studies specific to the older adult population were nominal. In addition, the results from these studies, which included subjects of various ages, were conflicting. Ribeiro et al (2017), in their systematic review on older adults with BPPV, concluded that postural balance and function were hardly investigated despite their clinical relevance in this patient population.

Patients with BPPV do not only experience physical symptoms such as vertigo, postural instability, and nausea/vomiting. They may also experience disruptions at the activity and participation domains, and develop negative emotions

(anxiety, depression, and fear-avoidance). Several studies had established that patients with BPPV experienced anxiety and negative emotions both before and after BPPV treatment (Kahraman et al., 2017; Ozdilek, Yalinay Dikmen, Acar, Ayanoglu Aksoy, & Korkut, 2019; Pollak et al., 2003; Pollak et al., 2012). However, evidence specific to older adults is very sparse. In a cross-sectional study of 44 older adult patients with chronic dizziness (Peluso, Quintana, & Ganança, 2016), most of them had dizziness for over a year and the most prevalent diagnosis was BPPV (52%). These older adults were found to have anxiety disorders and moderate-to-severe depressive disorders both in their lifetime and in the past 12 months (Peluso et al., 2016). A recent study found that older adults who had BPPV or general dizziness/impaired balance had poorer health-related quality of life, more tiredness, increased number of falls, and slower walking speed (Lindell, Kollén, Johansson, Karlsson, Rydén, Falk Erhag, et al., 2020). Against the backdrop of declining physical and vestibular functions, older adults with BPPV may be more affected and at increased risk of falls and injuries. Hence it is pertinent to include various functional/physical, subjective, and mental health outcomes when determining the success of BPPV management in this patient population.

There is also insufficient falls data in older adults with BPPV. One study showed that while the number of falls was significantly reduced, 85% of the older adults continued to fall in the 12 months follow-up period despite being effectively treated for BPPV (Gananca et al., 2010). A more recent study showed similar results: significantly reduced number of falls in the six months post treatment but 30 out of 40 subjects continued to experience at least one fall (Jumani & Powell, 2017). More research on falls monitoring and prevention in the BPPV population, especially in older adults, is needed.

2.3.1.3 Residual dizziness

Patients who have been successfully treated of BPPV may continue to complain of non-vertiginous dizziness and/or feeling unsteady on their feet, and this is known as residual dizziness (Seok et al., 2008). The prevalence of residual dizziness reported ranged from 31% to 63% (Abou-Elew et al., 2011; Faralli et al., 2016; Seok et al., 2008; Teggi et al., 2011; Teggi et al., 2013). Possible contributing factors discussed in the literature include delayed vestibular adaptation; otolithic dysfunction, more specifically utricular dysfunction; persistent otoconia debris in the

semicircular canal(s), but too small to bring on positive positional tests; anxiety; duration of BPPV symptoms prior to treatment; and co-existing vestibular conditions (Giommetti et al., 2017; Teggi & Nuti, 2017). Seok et al (2008) reported that 61% of their subjects had residual dizziness despite BPPV resolution. The only predictor was longer duration of BPPV symptoms; age and the other demographic/clinical parameters were not associated with residual dizziness (Seok et al., 2008). Teggi et al (2011) reported a prevalence of 37% of residual dizziness in adults aged ≥ 65 years old, and this was highest in those aged more than 72 years old. A later study, on adults with BPPV below 60 years old, reported a similar residual dizziness prevalence of 31% (Teggi et al., 2013). The duration of vertigo (BPPV symptom), and not age, was significantly associated with residual dizziness (Teggi et al., 2013). Two recent studies found significant age differences between those who with (≥ 65 years old) and without residual dizziness (< 65 years old) (Martellucci et al., 2016; Vaduva et al., 2018). In addition to the conflicting evidence discussed, it is also unclear on the following: (i) what are the factors associated with residual dizziness in older adults with BPPV; and (ii) what is the impact of residual dizziness on these older adults, functionally and psycho-emotionally?

2.3.1.4 Personal experiences – qualitative evaluation

Finally, the current evidence on the psycho-emotional impact of BPPV are often captured quantitatively via patient-reported outcomes such as the Dizziness Handicap Inventory and quality-of-life questionnaires. While these results may provide the objective findings and evaluations to BPPV management, they are unable to provide researchers and clinicians with the specific and intricate experiences of patients with BPPV. This is especially important for the older adult population; whose dizziness problems are often “unseen” and ubiquitously attributed to ageing. There is the need for a more qualitative approach to gathering information and gaining insights into the experiences of older adults with BPPV. The knowledge will help both researchers and clinicians better evaluate and improve future research and management for this patient population.

2.4 Summary of Literature Review

In summary, while repositioning manoeuvres are effective treatment for BPPV, some evidence points to less optimal recovery and more recurrence in older

adults with BPPV. Residual dizziness in older adults, and its associated factors and outcomes, are also poorly understood. In addition to a paucity of BPPV studies specific to the older adult population, evidence on their mental health, mobility, balance, falls risk, and quality of life are also lacking. To date, much is unknown about the lived experiences of this patient population.

This thesis aims to address the gaps identified through a series of studies which are presented in the subsequent chapters. In the next chapter (Chapter 3), a systematic review and meta-analysis on poor treatment outcomes in older adults post repositioning manoeuvres is presented. This systematic review was undertaken to review the current literature to identify poor outcomes of various domains (BPPV status, physical, and subjective) in older adults; and to compare their recovery with their younger counterparts. The subsequent chapters (Chapters 5 – 7) address the following areas in older adults with BPPV: (i) physical and self-report measures of older adults with BPPV before and after initial repositioning manoeuvres (compared to comparison controls); (ii) factors associated with residual dizziness; (iii) physical and self-report measures associated with residual dizziness; (iv) the patterns of change in BPPV status, recurrence, and falls over six months' follow-up; and (v) the experiences of older adults on how BPPV and its related management impact on the psychosocial and physical aspects of their lives.

Chapter 3 Poor Treatment Outcomes following Repositioning Manoeuvres in Younger and Older Adults with Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis

This chapter was published online in the Journal of the American Medical Directors Association, 20(2), 224.e221-224.e223, doi:https://doi.org/10.1016/j.jamda.2018.11.019 (see Appendix A for published article, Appendix B for the attribution statement, and Appendix C for copyright statement).

3.1 Abstract

Objective:

This systematic review aimed to methodically review the available evidence on poor treatment outcomes after repositioning manoeuvre treatments in adults with BPPV and whether there are differences in the outcomes for older and younger adults.

Data sources:

Embase, CINAHL, Scopus, PsycINFO (Ovid), Central Register of Controlled Trials (CENTRAL) and PubMed.

Review methods:

Studies were included if they were prospective experimental or observational studies with a minimal follow-up of one month; the subjects were at least 18 years old, had BPPV and were treated with repositioning manoeuvres. Studies were excluded if they were not available in English full-text and if the outcomes used were confined to positional test and subjective vertigo rating. Methodological quality was assessed using the Joanna Briggs Institute Critical Appraisal Checklists. Meta-analysis was performed to compare outcomes for younger and older (≥60 years old) subjects where multiple studies utilised similar outcomes.

Results:

Thirty-five studies were selected. The methodological quality was poor in more than 60% of the studies. Treatment efficacy, based on positional test results and symptom resolution, and recurrence were the most common outcomes. Balance and quality of life measures improved after treatment but were not always normalised. Residual symptoms and psycho-emotional consequences persisted in some subjects, despite BPPV resolution. Meta-analyses indicated poorer dynamic balance recovery and increased self-perceived level of handicap in the older group relative to the younger group.

Conclusions and Implications:

Although repositioning manoeuvres were effective in BPPV management, some patients experienced residual dizziness, postural instability, recurrences, and psycho-emotional consequences at least one month after repositioning. Moreover, older adults experienced less improvements in dynamic balance and self-perceived handicap rating compared with younger people. These issues may further impact on

older adults with BPPV physically and mentally and should be addressed by future better quality research and interventions.
Keywords

Benign Paroxysmal Positional Vertigo, repositioning manoeuvres, treatment outcomes, residual dizziness, recurrence, older and younger adults

3.2 Introduction

One of the most common peripheral vestibular conditions is Benign Paroxysmal Positional Vertigo (BPPV). BPPV is characterised by episodes of intense vertiginous giddiness, usually lasting less than a minute, triggered by specific head positions (Smouha, 2013). An epidemiological study (von Brevern et al., 2007) reported a one-year incidence rate of 0.6% and prevalence of 1.6%. The one-year prevalence for adults older than 60 years old was 3.4% compared with 0.5% for those between 18 to 39 years old, and 1.7% for adults between 40 to 59 years old (von Brevern et al., 2007).

Considerable research in BPPV has focused on exploring the treatment. Physical treatment for BPPV using repositioning manoeuvres is well documented to be more efficacious, when compared with medications or no treatment (T. D. Fife et al., 2008). Treatment efficacy of the Epley Manoeuvre was reported to be as high as 90%-100% in the first two sessions (Reinink et al., 2014). Treatment efficacy for other manoeuvres ranged from 60% to over 90% (Anagnostou et al., 2015; Y. Chen et al., 2012; Kinne et al., 2012). Most of these studies focused primarily on treatment efficacy measured predominantly using positional tests, and the subjective self-report (symptom intensity/handicap). However, consideration of only these two outcome domains might not provide a complete picture of recovery. Poor treatment outcomes, such as balance impairment, dizziness, and anxiety, despite negative Dix-Hallpike test being achieved, have been reported in a small number of studies (Abou-Elew et al., 2011; Anagnostou et al., 2015; Y. Chen et al., 2012; Di Girolamo et al., 1998; Kinne et al., 2012; Pollak et al., 2012; Seok et al., 2008; Teggi et al., 2013). In addition, there remained a proportion of patients who did not respond favourably, or who had recurrence of symptoms after resolution of BPPV (Beynon, Baguley, & Da Cruz, 2000; Pérez et al., 2012). Several studies found that older adults, compared to younger adults, were more likely to experience such unfavorable outcomes (Babac et al., 2014; Blatt et al., 2000; Teggi et al., 2011), while other studies did not find an age difference (Kasse et al., 2012; Pollak, Kushnir, Shpirer, Zomer, & Flechter, 2005; Vaz et al., 2013).

The aim of this systematic review was to methodically review the current evidence on treatment outcomes after repositioning manoeuvres in adults with BPPV to answer the following questions: (i) Are there poor short- and long-term outcomes seen in adults with BPPV following initial repositioning manoeuvres, and what

factors are associated with these poor outcomes? and (ii) Do older adults with BPPV experience different outcomes compared with younger adults? To date, there have been no systematic reviews on poor treatment outcomes post repositioning manoeuvres in younger and older adults with BPPV.

3.3 Methods

Poor outcomes were defined as any remaining vertigo, dizziness, unsteadiness, and/or suboptimal changes in objective assessments despite adequate repositioning manoeuvres and BPPV resolution. Short-term and long-term were defined as one month and six months from the initial repositioning treatment, respectively. For this systematic review, dizziness, vertigo, and unsteadiness were defined according to the International Classification of Vestibular Disorders I (ICVD-I) developed by the Committee for the Classification of Vestibular Disorders of the Bárány Society (A. R. Bisdorff, Staab, & Newman-Toker, 2015). Dizziness was defined as “the sensation of disturbed or impaired spatial orientation without a false or distorted sense of motion” and is non-vertiginous in nature (A. Bisdorff, von Brevern, Lempert, & Newman-Toker, 2009, p. 7). Vertigo was “the sensation of self-motion when no self-motion is occurring or the sensation of distorted self-motion during an otherwise normal head movement” (A. Bisdorff et al., 2009, p. 5). It also included false sensations such as spinning, swaying, tilting, bobbing, bouncing, or sliding (non-spinning vertigo) (A. Bisdorff et al., 2009).

Unsteadiness was defined as “the feeling of being unstable while seated, standing, or walking without a particular directional preference” (A. Bisdorff et al., 2009, p. 9) and should decrease or be eliminated by added support such as holding onto a stable wall (A. Bisdorff et al., 2009). Balance impairment was defined as “reduced performance, when compared with normative data, on standardised assessment procedures to measure postural control”. The assessment procedures might include simple clinical measures such as timed balance tests, functional gait and balance tests, posturography using the Neurocom® Balance Master or laboratory measures using force plates.

Searches were conducted using Embase, CINAHL, Scopus, PsycINFO (Ovid), Central Register of Controlled Trials (CENTRAL) and PubMed for papers published from 1997 to August 2018. The reference lists of retrieved relevant papers were also hand searched. The keywords used for searching the literature were

formulated using the PICO strategy and adapted for the different databases. An example of the search strategy adapted for Pubmed is outlined below (see Table 3.1).

Table 3.1 Search strategy adapted for Pubmed

1. Benign Paroxysmal Positional Vertigo [MeSH] OR Benign Paroxysmal Positional Vertigo OR BPPV OR BPV
2. Adult* OR patient* OR older p* OR person* OR geriatric*
3. (repositioning man*) OR (canalith repositioning) OR (particle repositioning) OR (epley man*) OR (semont man*) OR (lempert man*) OR (gufoni man*) OR (appiani man*) OR (casani man*)
4. outcome* OR (treatment failure*) OR result* OR vertigo OR dizz* OR imbalance OR unstead* OR (poor balance) OR (postural instability) OR anxi* OR depress* OR (mental health)
5. 1 AND 2 AND 3 AND 4

The population included in this review was adults with BPPV aged 18 years and above. The diagnosis of BPPV must have been confirmed with positional tests. The focus treatment was the current office treatment using repositioning manoeuvres (i.e., non-surgical and non-pharmaceutical treatments). These manoeuvres included the Epley, the Semont, the Deep Head Hanging, the Lempert, and the Gufoni. Studies investigating medications, self-treatment and vestibular rehabilitation were included if the interventions were studied in combination with the repositioning manoeuvres. The rationale for these inclusion criteria for intervention type was that they are the commonly used treatment approaches for BPPV and have good research evidence of short term effectiveness (Bhattacharyya et al., 2017). Studies that included mainly participants with multiple canals- or bilateral- BPPV or which reported dizziness/vertigo not related to BPPV were excluded. Only prospective experimental or observational studies in English were included. The studies needed to incorporate a minimum total follow-up period of one month. Included studies must have incorporated, not including positional tests and self-report dizziness measures, additional outcome measures.

After duplicates were removed, the studies were screened using title and abstract, after which potential studies were further assessed using full text. The final selection of articles was assessed for methodological quality using the Joanna Briggs Institute Critical Appraisal Checklists (The Joanna Briggs Institute, 2014) by two independent reviewers. The team discussed and standardised the method of rating for the intention-to-treat and the control of other interventions criteria. The final score was based on the total number of criteria rated as “Yes”.

Data were extracted using standardised forms for participants in the repositioning manoeuvres-only groups, with the consideration that the main effects were influenced only by such interventions. The only exception was recurrence, for which results were reported for any group with repositioning manoeuvres. Where information was lacking, the authors were contacted by email to request additional details.

For exploring the difference in outcomes between older and younger adults, we assigned the “older adult population” for the studies with a mean/median age of 60 years old and above. Studies were classified as having a “younger adult population” if they reported a mean/median sample age of less than 60 years old. Data were synthesized using a narrative format with meta-analysis planned when appropriate. This systematic review was performed and reported in accordance with the PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman, & Group, 2009).

3.4 Results

3.4.1 Study selection

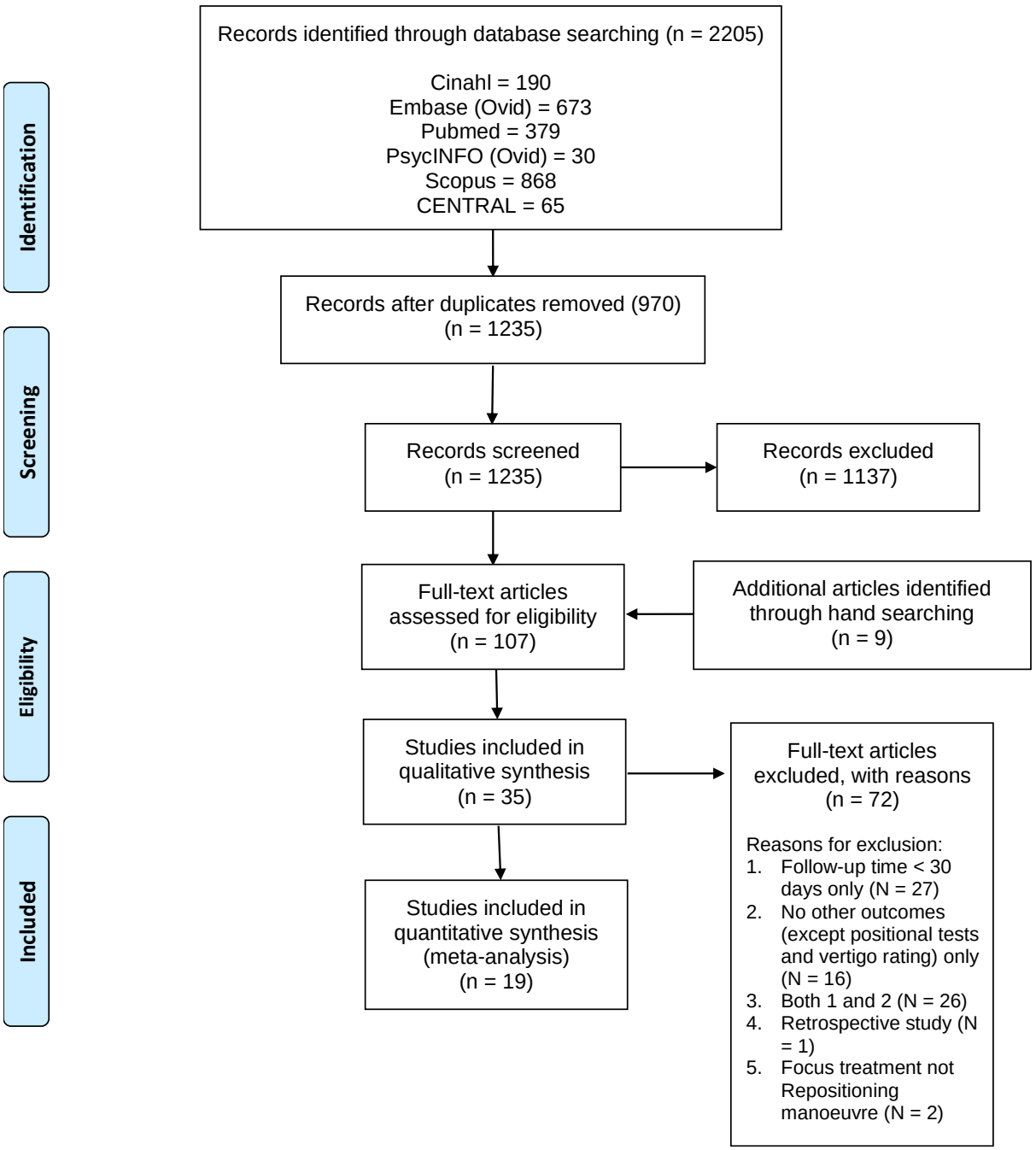
A total of 2205 studies were retrieved from the databases. After removal of duplicates and initial screen of titles and abstracts, 98 studies remained. Nine other studies were identified through hand searching. One-hundred and seven full texts were evaluated. Seventy-two studies were further excluded: 27 for not meeting follow-up criterion; 16 did not meet the outcomes criterion; 26 studies did not meet both criteria; one was a retrospective study and another two for treatment outside the scope defined for inclusion in the review. Thirty-five studies were included (Cetin et al., 2018; Chang, Yang, Hsu, Chern, & Wang, 2008; Cohen & Kimball, 2005; Di Girolamo et al., 1998; Gamiz & Lopez-Escamez, 2004; Giacomini, Alessandrini, & Magrini, 2002; R. Hoseinabadi, Pourbakht, Yazdani, Kouhi, & Kamali, 2016; Jozefowicz-Korczynska, Pajor, & Skora, 2018; Kahraman et al., 2017; Kaur &

Shamanna, 2017; Khatri, Raizada, & Puttewar, 2005; E. J. Kim, Oh, Kim, Yang, & Yang, 2015; Y. K. Kim, Shin, & Chung, 2005; L. Kollén, Bjerlemo, & Möller, 2006; Lopez-Escamez, Gamiz, Fernandez-Perez, & Gomez-Finana, 2005; Lopez-Escamez, Gomez Fiñana, Fernandez, Gámiz, & Sanchez-Canet, 2003; Maslovara et al., 2017; Maslovara, Soldo, Puksec, Balaban, & Penavic, 2012; Mendes, Maslovara, Vceva, & Soldo, 2017; Mujeeb & Khan, 2000; Nunez, Cass, & Furman, 2000; Ouchterlony, Masanic, Michalak, Topolovec-Vranic, & Rutka, 2016; Pollak et al., 2012; Prokopakis et al., 2013; Prokopakis et al., 2005; Rashad, 2009; Ribeiro et al., 2016; Ribeiro, Freitas, Ferreira, Deshpande, & Guerra, 2017; Salvinelli et al., 2004; Sato, Sekine, Matsuda, & Takeda, 2013; Sekine et al., 2006; Sridhar et al., 2003; J. Tan, Deng, Zhang, & Wang, 2017; Wang, Xia, Wang, & Hu, 2018; Yimtae, Srirompotong, & Sae-Seaw, 2003) (see Figure 3.1).

3.4.2 Subject and study characteristics

There were 3834 participants (range 9 to 965) with BPPV in the included studies. The mean age of the participants ranged between 32 and 74 years old in 29 studies. Three studies reported median ages above 60 years old (Gamiz & Lopez-Escamez, 2004; E. J. Kim et al., 2015; Maslovara et al., 2017; Mendes et al., 2017. Ten out of 35 studies comprised subject populations with a mean/median age of 60 years old and above {De Figueiredo Ribeiro, 2016 #233; Nunez et al., 2000; Ribeiro et al., 2016; K. M. Ribeiro et al., 2017; Salvinelli et al., 2004; Sato et al., 2013; Wang et al., 2018, including four on older adults only (aged 60 years and above) {De Figueiredo Ribeiro, 2016 #233). There were 2113 female participants reported across 32 studies. Five studies included healthy controls as comparisons (Di Girolamo et al., 1998; Giacomini et al., 2002; Kahraman et al., 2017; E. J. Kim et al., 2015; Maslovara et al., 2012)

Figure 3.1 PRISMA flow diagram for the screening process



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

There were 11 randomized controlled trials (Cetin et al., 2018; Chang et al., 2008; Cohen & Kimball, 2005; Gamiz & Lopez-Escamez, 2004; Giacomini et al., 2002; R. Hoseinabadi et al., 2016; Jozefowicz-Korczynska et al., 2018; Kahraman et al., 2017; Kaur & Shamanna, 2017; Khatri et al., 2005; E. J. Kim et al., 2015; Y. K. Kim et al., 2005; L. Kollén et al., 2006; Lopez-Escamez et al., 2005; Lopez-Escamez

et al., 2003; Maslovara et al., 2017; Maslovara et al., 2012; Mendes et al., 2017; Mujeeb & Khan, 2000; Nunez et al., 2000; Ouchterlony et al., 2016; Pollak et al., 2012; Prokopakis et al., 2013; Prokopakis et al., 2005; Rashad, 2009; Ribeiro et al., 2016; K. M. Ribeiro et al., 2017; Salvinelli et al., 2004; Sato et al., 2013; Sekine et al., 2006; Sridhar et al., 2003; J. Tan et al., 2017; Yimtae et al., 2003, 23 quasi-experimental studies {Di Girolamo, 1998 #244) and one cohort study (Wang et al., 2018). In all studies, the diagnosis of BPPV was confirmed with positive positional tests (Dix-Hallpike and roll tests). Eight studies had a follow-up time of one month (Chang et al., 2008; Di Girolamo et al., 1998; Gamiz & Lopez-Escamez, 2004; R. Hoseinabadi et al., 2016; Kaur & Shamanna, 2017; Lopez-Escamez et al., 2003; Sekine et al., 2006; Yimtae et al., 2003) while nine had follow-up duration greater than one month to less than six months (Giacomini et al., 2002; E. J. Kim et al., 2015; Maslovara et al., 2012; Ouchterlony et al., 2016; Pollak et al., 2012; Ribeiro et al., 2016; K. M. Ribeiro et al., 2017; Sato et al., 2013; J. Tan et al., 2017). The follow-up time for the remaining 18 studies were from six months to five years (Cetin et al., 2018; Cohen & Kimball, 2005; Jozefowicz-Korczynska et al., 2018; Kahraman et al., 2017; Khatri et al., 2005; Y. K. Kim et al., 2005; L. Kollén et al., 2006; Lopez-Escamez et al., 2005; Maslovara et al., 2017; Mendes et al., 2017; Mujeeb & Khan, 2000; Nunez et al., 2000; Prokopakis et al., 2013; Prokopakis et al., 2005; Rashad, 2009; Salvinelli et al., 2004; Sridhar et al., 2003; Wang et al., 2018) (see Table 3.2).

Table 3.2 Summary of study characteristics and results

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Cetin et al 2018 RCT	N = 50; 29 females 21 males Mean age 56.4 (11.3); Unilateral Posterior Canal BPPV;	Experimental: Epley Manoeuvre (25) Control: Brandt-Daroff exercise (25)	1. Recovery rates 2. Recurrence Week 1 after treatment Week 2 Week 3 Average follow-up of 18 months	For Epley Manoeuvre group only: Recovery rates: Week 1 - 19 (76%) Week 2 - 24 (96%) (cumulative) Week 3 - 25 (100%) (cumulative) Recurrence: 7/25 (28%)
Chang et al 2008 RCT	N = 26; Mean age 54.1 (10.9); Unilateral Posterior Canal BPPV	Experimental: Canalith Repositioning Manoeuvre + Vestibular exercises (13) Control: Canalith Repositioning Manoeuvre (13)	1. Standing on foam 2. Single leg stance 3. Tandem walk 4. Dynamic Gait Index 5. Visual Analogue Scale (dizziness intensity) Baseline 2 weeks 4 weeks	In total, 12/13 (92.3%) in the Canalith Repositioning Manoeuvre only group achieved a negative Dix-Hallpike Test. Number of subjects with normal sway velocities at the end of the study: Foam eyes open 12/13 (92%); eyes closed 5/13 (38%) Single leg standing eyes open 13/13 (100%); eyes closed 1/13 (8%) Tandem walk end-sway 7/13 (54%) Dynamic Gait Index: from 19.8 (2.8) to 22.5 (1.4) ($p < .01$) Visual Analogue Scale (dizziness intensity): from 5.1 (1.6) to 1.0 (1.0) ($p < .01$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Cohen and Kimball 2005 RCT	N = 124; Mean age 58.3 (12.8); Unilateral Posterior Canal BPPV	Experimental: Canalith Repositioning Procedure (24) Lempert's Manoeuvre (25) Brandt-Daroff Exercise (25) Habituation Exercise (25) Control: Sham Manoeuvre (25)	1. Visual Analogue Scale (vertigo intensity) 2. Visual Analogue Scale (vertigo frequency) 3. Sensory Organisation Test condition 5 score Baseline 1 week 3 months 6 months	The Canalith Repositioning Procedure, Lempert's Manoeuvre and Brandt-Daroff groups performed better than the Habituation Exercise and Sham Manoeuvre groups 1. Vertigo Intensity and frequency: ↓sharply and sig. in first 60- and 90- days respectively ($p < .0001$) then plateaued 2. Sensory Organisation Test condition 5 score: 57% of subjects with abnormal baseline scores had sharp improvements in the first 60 days ($p < .0001$) BUT levelled off after that
Gamiz and Lopez-Escamez 2004 QE	N = 32; Mean age (years) 66.8±5.7; Unilateral Posterior Canal BPPV;	Experimental: A single Particle Repositioning Manoeuvre without mastoid oscillation (32) Control: Nil	1. Dix-Hallpike Test 2. 36-Item Short Form Survey (SF36) 3. Dizziness Handicap Inventory-short (DHI-S) Baseline 30 days	Dix-Hallpike Test: Negative: 24/29 (83%); - Positive: 5/29 (17%) 36-Item Short Form Survey: All domains had significant improvements except Physical Function, Role limitation due to emotional problems and General Health. Domains that did not normalise: Role limitation due to physical problems and Role limitation due to emotional problems. Dizziness Handicap Inventory-short (out of 40): 17.19 (9.06) → 9.70 (10.13) ($p < .0001$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Giacomini et al 2002 QE	BPPV group = 20; Mean age (years) 45.0 (3.6); Unilateral Posterior Canalithiasis with resolution of BPPV within 3 days after undergoing Canalith Repositioning Manoeuvre; Normal controls = 20; Age- and gender-matched	Experimental: Canalith Repositioning Manoeuvre (20) Control: Nil	1. Static posturography 1 hour after diagnostic manoeuvre (baseline) 3 days (compared with baseline and 12 weeks) 12 weeks (compared with 3 days post treatment and normal controls)	Sway velocity (*M*): Eyes open: Baseline 8.3 (3.1) (sig. different from control) 3 days 9.4 (2.9) 12 weeks 5.4 (2.9) (not sig. different compared with control) Eyes closed: Baseline 11.0 (2.4) (sig. different from control) 3 days 12.3 (4.0) 12 weeks 9.6 (3.0) (not sig. different compared with control) Baseline: sig. differences in lateral and anterior-posterior planes of body sway between BPPV and Control group ($p \leq .05$) 3 days: sig. within-group changes from baseline ($p < .05$) only seen in frontal (x) plane for BPPV group. 12 weeks: Sig. within-group changes from 3 days ($p < .05$) only seen in sagittal (y) plane for BPPV group. No sig. between group differences found at 12 weeks for all parameters.

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Girolamo et al 1998 QE	BPPV group = 32; Idiopathic Posterior Canal BPPV; Mean age (years) Female 51.6 Male 53.0; Normal controls = 32; Age- and gender-matched	Experimental: Lempert's Manoeuvre (32) Control: Nil	1. Sensory Organisation Test (SOT) Baseline 3 days 1 month	SOT scores (n = 30 Resolved BPPV): <u>Baseline →1 month</u> Composite 64.0 (12.7) → 72.0 (7.6) Somatosensory 97.0 (40.0) → 100.0 (10.0) Visual 74.0 (23.0) → 82.0 (18.0) Vestibular 48.0 (24.0) → 67.0 (17.0) Preferential 95.0 (17.0) → 89.0 (9.0) Significant improvements from baseline ($p \leq .05$) but still differs sig. from those of the normal controls ($p < .05$) for conditions 2-6.
Hoseinabadi et al 2016 QE	N = 30; Unilateral Posterior Canal BPPV; Group A: With otolith problems = 15; Mean age (years) 44.8 (9.7) Group B: Without otolith problems = 15; Mean age (years) 45.5 (7.4) Vestibular Evoked Myogenic Potential test was used to determine presence of otolith problems	Experimental: Epley's Manoeuvre (30) Control: Nil	1. Dizziness Handicap Inventory - Total - Functional - Emotional - Physical Baseline 1 month after successful treatment	Dizziness Handicap Inventory (DHI): <u>Total score</u> Baseline: Group A 34.13 (7.65); Group B 25.46 (10.23) ($p = .02$) 1 month: Group A 9.20 (8.16); Group B 4.13 (5.26) ($p = .05$) <u>1 month after successful treatment</u> Group A results: DHI Total, Physical and Functional scores, differed sig. from those of Group B ($p \leq .05$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Józefowicz-Korczyńska et al 2018 QE	N = 9; Mild Traumatic Brain Injury (MTBI) with BPPV; 8 Posterior Canal BPPV 1 Lateral Canal BPPV; Mean age (years) 42.3 (18.7); 4 females 5 males	Experimental: Epley's Manoeuvre (8) Barbeque Roll (1) Control: Nil	1. BPPV occurrence 2. Treatment outcome 3. Recurrence Baseline 2 weeks after treatment 4 weeks	BPPV occurrence: - Out of 179 cases, 19 complained of positional vertigo. - 9 out of 19 had BPPV confirmed through positional tests Treatment outcome: 4/9 (44.4%) required a second manoeuvre 2 weeks after initial treatment – thereafter tested negative on positional tests Recurrence: 1/9 (12.5%) had a recurrence at 2 years follow-up
Kahraman et al 2016 QE	N = 32; 30 Posterior BPPV 2 Lateral BPPV Mean age 52.0 (14.2) Normal controls = 32; Age- and gender-matched; Mean age (years) 52.9 (15.3)	Experimental: Modified Epley's or Barbeque Manoeuvre (as appropriate)(30) Control: Nil	1. Beck Anxiety Inventory 2. Panic Agoraphobia questionnaire 3. Time to end of vertigo and unsteadiness Baseline 7 days 14 days 6 months	<u>Success rate</u> 1st treatment: 68.8%; 2nd treatment: 90.6% <u>Beck Anxiety Inventory</u> Baseline: 20.91 (12.31) → 14 days: 4.93 (7.00) (both results were sig. worse when compared with controls, $p < .05$) <u>Panic Agoraphobia</u> Baseline: 27.84 (17.60) → 14 days: 6.56 (6.33) (both results were sig. worse when compared with controls, $p < .05$) <u>Mean time (days) to:</u> Negative positional tests 11.16 (8.60) Correction of vertigo 32.69 (24.68) Correction of unsteadiness 25.41 (28.60)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Kaur and Shamanna 2017 Randomised Trial	N = 90; 43 females 47 males Age range (years) 20 to 60 Epley only group = 30; Age mean (years) 41.3 (11.4) Betahistine only group = 30; Not given Epley+Betahistine group = 30; Age mean (years) 42.1 (13.0) All 3 groups were age- and gender-matched	Unclear which were the experimental or control groups Epley vs Betahistine vs Epley+Betahistine	1. Treatment efficacy 2. Visual Analogue Scale (VAS) vertigo 3. Dizziness Handicap Inventory (DHI) 1 week after treatment 4 weeks	Epley only group: Treatment efficacy: - 1 subject did not respond to treatment at all - 1 subject (3.3%) had a recurrence at 4 weeks <u>VAS (*M*)</u> Pre-treatment 7.80 (0.94) 1-week post-treatment 2.40 (1.28) 4 weeks post-treatment 2.17 (1.28) (sig. changes with $p = .001$) DHI Sig. improvement (-40 points) from pre-treatment ($p < .001$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Khatri et al 2005 QE	N = 62; Posterior Canal BPPV; Subject gender ratio and age were not provided.	Experimental: Canalith Repositioning Manoeuvre: - with Mastoid oscillation (28) - without mastoid oscillation (34) Control: Nil	1. Subjective: Visual Analogue Scale: Grade I (complete) - no vertigo on provocative head/body positioning during the entire follow up; Grade II (partial response) – >50% reduction on provocative positioning or ill-defined imbalance only Grade III (no response) – no definition provided 2. Objective: Dix-Hallpike test: Type I - no positional nystagmus after 1 month Type II - minimal nystagmus Type III - continued to have positional nystagmus 3. Recurrence After treatment 7 to 10 days 15 to 20 days > 1 month 6 months	Combining both groups (N = 62): Subjective: <u>7 to 10 days after treatment</u> Grade I 32 (51.6%); Grade II 26 (41.9%); Grade III 4 (6.5%) <u>15 to 20 days</u> Grade I 50 (80.6%); Grade II 10 (16.1%); Grade III 2 (3.2%) <u>> 1 month</u> Grade I 53 (85.5%); Grade II 7 (11.3%); Grade III 2 (3.2%) Objective: <u>7 to 10 days after treatment</u> No positional nystagmus (I) 38 (61.3%); Minimal nystagmus (II) 20 (32.3%); Positional nystagmus (III) 4 (6.5%) <u>15 to 20 days</u> (I) 50 (80.6); (II) 10 (16.1%); (III) 2 (3.2%) <u>> 1 month</u> (I) 54 (87.1%); (II) 6 (9.7%); (III) 2 (3.2%) Recurrence (n = 38) at 6 months: 7 (18.4%)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Kim et al 2005 QE	N = 30; Anterior Canal BPPV; Mean age (years) 55.5 (9.1) 18 out of 30 subjects also had concurrent Posterior Canal BPPV	Experimental: Canalith Repositioning Procedures (30) Control: Nil	1. Treatment efficacy rated by: - Grade I: All vertigo and nystagmus resolved - Grade II: BPPV resolved, other vertigo remains 2. Recurrence Assessment done 2 weeks after final CRP	Treatment efficacy: - Grade I (All vertigo and nystagmus resolved): n = 29 - Grade II (BPPV resolved, other vertigo remains): n = 1 Recurrence (n = 4): - 13% for anterior BPPV - 10% for posterior or lateral BPPV
Kim et al 2015 QE	N = 102; 1st attack of idiopathic unilateral BPPV - 47 posterior canal - 51 lateral canal - 4 mixed; Mean age (years) 62.8 (13.1); Healthy controls = 50; Mean age (years) 60.1 (range 43-76)	Experimental: Repositioning manoeuvres (did not specify the exact ones used) (102) Control: Nil	1. Vestibular Evoked Myogenic Potential (Cervical) 2. Vestibular Evoked Myogenic Potential (Ocular) Before treatment 2 months after successful resolution of nystagmus and vertigo	Baseline: Proportion of abnormal vestibular evoked myogenic potential is sig. higher in the BPPV group compared with healthy controls ($p < .01$) Two months after successful treatment: - 59 out of 102 (57.8%) successfully treated - No sig. changes from the initial values for both affected ($p = .32$) and non-affected ears ($p = .65$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Kollen et al 2006 QE	N = 17; Posterior Canal BPPV; Mean age (years) 52 (range 31-66)	Experimental: Semont (17) Brandt-daroff exercises if Dix-Hallpike test still positive after two Semont treatment (8) Control: Nil	1. Dix-Hallpike Test 2. Static Balance: - Sharpened Romberg - Standing on 1 leg 3. Dynamic Balance: - Walking 10m - Walking 10m with horizontal head turns - Walking with vertical head turns 4. Visual Analogue Scale: unsteadiness and vertigo 5. Questions on general health and changed activities Baseline 1 month 6 months 12 months	Negative Dix-Hallpike Test: - 1 month: 11/17 (65%); 6 and 12 months: 14/17 (82%) Static Balance (Standing on one leg and Sharpened Romberg, eyes open/closed): no sig. changes throughout($p > .05$) Dynamic Balance: Walking speed (m/s) (all changes were significant, $p \leq .05$) <u>Normal</u> 1.10 (0.20) →1.25 (0.21) <u>Walking with horizontal head turns (speed, m/s)</u> 1.0 (0.24) →1.2 (0.23) <u>Walking with vertical head movements (speed, m/s)</u> 1.0 (0.20) →1.2 (0.19) Step length (*M*, m): <u>Walk with horizontal head turns</u> Baseline 0.61; 6 and 12 months 0.66 <u>Walk with vertical head movements</u> Baseline 0.58; 6 and 12 months 0.70 Visual Analogue Scale for unsteadiness and vertigo: - Dizziness ↓sig. over 12 months but for those with resolved BPPV, values did not reach 0. - Unsteadiness (standing and walking) ↓sig. in the first month ($p < .01$) but remained the same after 12 months. 9/17 subjects still complained of unsteadiness at end of study.

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Lopez-Escamez et al 2003 QE	N = 40; Posterior Canal BPPV; Mean age (years) 50.1 (13.5) Gender ratio not reported	Experimental: Single Particle Repositioning Manoeuvre (40) Control: Nil	1. Dix-Hallpike test (at 30 days) 2. 36-Item Short Form Survey 3. Dizziness Handicap Inventory short (DHI-S) Baseline 7 days 30 days	Dix-Hallpike Test (at 30 days): Negative 28/37 (76%); Positive 9/37 (24%) 36-Item Short Form Survey: - 30 days: All domains improved except General Health and Role limitation due to emotional/personal problems (no change) Dizziness Handicap Inventory short: Baseline 18.0 (9.91); 30 days 9.54 (9.94) (p < .001)
Lopez-Escamez et al 2005 QE	N = 50; Unilateral Posterior canal BPPV; - 35 females - 15 males Mean age (years) 55.1 (15.3)	Experimental: Single Particle Repositioning Manoeuvre without mastoid oscillation (50) Control: Nil	1. 36-Item Short Form Survey 2. Dizziness Handicap Inventory short Baseline 30 days 60 days 180 days 360 days	Dix-Hallpike Test: 30 days: Negative 40/50 (80%); Positive 10/50 (20%) 180 days: Positive 7/50 (14%) 360 days: Positive 5/50 (10%) Persistent BPPV: 2/50 (4%) Recurrence: 3/50 (7.5%) 36-Item Short Form Survey: - Improvements in Physical functioning, Role limitation due to physical functioning, Social function, Vitality and Mental health (p > .05) but only Vitality score reached normative value; - No change: General health, Bodily pain and Role limitation due to emotional/personal problems - No difference in scores between subjects with negative and positive Dix-Hallpike tests after treatment Dizziness Handicap Inventory Short total score (M - SD not provided): Baseline 18.19 → at 360 days 7.78 (p < .001)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Maslovara et al 2012 RCT	N = 96 BPPVs; Dizziness Handicap Inventory total score ≥40 Betahistine group = 48; 31 females 15 males Mean age (years) 52.6 (19-84); Epley group; 30 females 15 males Mean age (years) 53.5 (19-76); Healthy controls = 40; 16 females 24 males Mean age (years) 34.8 (23-56)	Experimental: Betahistine (48) Epley's manoeuvre (48) Control: Nil	1. Dix-Hallpike Test 2. Dizziness Handicap Inventory 3. 36-Item Short Form Survey 4. Hospital Anxiety and Depression Scale Baseline (T0) 1 week (T1) 8 weeks (T8)	Epley Group only: Positive Dix-Hallpike test: - 1 week 6.67%; 8 weeks 4.45% Dizziness Handicap Inventory-total (*Mdn*): - Baseline (T0): 72 (*IQR* 60.0-84.0) - 1 week (T1): 18 (*IQR* 16.0-34.0) - 8 weeks (T8): 10 *(IQR* 8.0-22.0) 36-Item Short Form Survey: (T0) 33.01; (T1) 58.44; (T8) 72.96 Hospital Anxiety and Depression Scale: Anxiety (*M*) (T0) 1.58 (0.30); (T1) 0.98 (0.53); (T8) 0.94 (0.21) Depression (*M*): (T0) 1.48 (0.26); (T1) 1.34 (0.15); (T8) 1.32 (0.12)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Maslovara et al 2017 QE	N = 40; Posterior Canal BPPV; - 29 females - 11 males Mean age (years) 64 (12)	Experimental: Epley Manoeuvre (40) Control: Nil	1. Recurrence 2. Vitamin D serum level 3. Calcium serum level After diagnosis (before treatment) 6 months after	Recurrence: - 5 out of 31 (16%) (did not provide reason for the difference in sample size) - No sig. correlation with age, gender, vitamin D and calcium levels ($p > .05$) Vitamin D serum level: - Inadequate or deficient in 82.5% of the subjects - Low levels more frequent in Canalithiasis cases (6/9) compared with Cupulolithiasis cases (5/10) (χ^2 test, $p = .036$) - Canalithiasis cases had sig. lower level (*Mdn* 18, *IQR* 15 - 20) compared with Cupulolithiasis cases (*Mdn* 27, *IQR* 22 - 32) ($p = .013$) Calcium serum level: No sig. abnormality in levels or differences between canalithiasis and cupulolithiasis types ($p > .05$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Mendes et al 2017 QE	N = 48; 33 females 15 males Median age (years) 63 (range 53-69)	Experimental: Epley Manoeuvre (48) Control: Nil	1. Vestibular Evoked Myogenic Potential (VEMP) test: Ocular (oVEMP) and Cervical (cVEMP) using (i) Latency; (ii) Peak-to-peak amplitude (PPA); and (iii) Amplitude ratio (AR) 2. Recurrence Before Epley After Epley 7 days after Epley 6 months after successful repositioning	Treatment efficacy: 2 repositioning procedures: 32/48 (66.7%) 4 repositioning procedures: 48/48 (100%) cVEMP: -No sig. changes for all parameters (latency, PPA and AR) across all measurements for both affected and non-affected ears ($p > .05$) oVEMP: - No sig. changes to latencies measured throughout ($p > .05$) - Increase in PPA for both ears up to 6 months after treatment but not sig. ($p > .05$) - Sig. improvements were seen in AR comparing: (i) baseline and 7 days after Epley ($p = .011$); and (ii) repeated measurements at all time points ($p = .039$) Recurrence: - 9/48 (18.8%), with sig. difference in both oVEMP AR and cVEMP AR between those with and without recurrence ($p < .05$) - oVEMP AR: the only sig. predictor of recurrence (77.8% sensitivity, 94.9% specificity, $p = .002$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Mujeeb and Khan 2000 QE	N = 21; 14 females 7 males Mean age (years) 46.6 (47%: between 40-60 years old)	Experimental: Epley's Manoeuvre + mastoid vibration (21) Control: Nil	1. Success of treatment: Grade I: negative Hallpike test after Epley's Grade II: Some vertiginous feeling on Hallpike test, although with considerable subjective improvement. Grade III: No subjective improvement and a positive Hallpike test 2. Recurrence Timelines not stated. Only mentioned "Follow-up ranged from 30 weeks to 112 weeks"	Success of treatment: Initial Grade I – 15 (71.4%); Grade II – 6 (28.6%); Grade III – 0 Final Grade I – 20 (95.2%); Grade II – 1 (4.85%); Grade III – 0 Recurrence: 3/21 (14.2%) within 1st three weeks
Nunez et al 2000 QE	N = 168; After 17 dropped out, 151 remained; 107 females 44 males Mean age (years) 63.0	Experimental: Canalith Repositioning Procedure ± mastoid vibration or manual tapping (151) Control: Nil	1. Treatment success 2. Recurrence Yearly phone calls were made for follow-ups	Treatment success: 1st treatment 131/151 (86.8%) 2nd treatment 138/151 (91.3%) Recurrence: 37/138 (26.8%) Mean time to recurrence (months) 13.6 (9.7)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Ouchterlony et al 2016 QE	3 groups: Group 1 Traumatic Brain Injury (TBI) + Posterior canal BPPV = 21; 6 females 15 males Age (*Mdn* years, *IQR*) 32.0 (21.0); 16 mild TBI 5 moderate TBI Group 2 TBI + non-specific dizziness (NSD) = 23; 11 females 12 males Age (*Mdn* years, *IQR*) 36.0 (26.0); All mild TBI Group 3 TBI + No dizziness group = 12; 5 females 7 males Age (*Mdn* years, *IQR*) 43.0 (26.3) All mild TBI	Experimental; Canalith Repositioning Procedure (21) for Group 1 only Control: Nil	1. Symptom resolution 2. 36-Item Short Form Survey (Physical and Mental Health components only) 3. Dizziness Handicap Inventory Baseline 1 week 5 weeks 9 weeks 12 weeks	TBI with BPPV group only (n = 16): Symptom resolution at 12 weeks Resolved 12 (75%); Unresolved 4 (25%) 36-Item Short Form Survey: While there was improvement in the Physical component scores over 12 weeks, the changes in the Mental Health component were negligible. Dizziness Handicap Inventory (*M*±*SEM*): Baseline 42.9±5.7 12 weeks 17.8±5.9 ($p \leq .05$)

				Dizziness Handicap Inventory (DHI): <u>Total score (*M*)</u> Before treatment 29.6 (17.1); After treatment 24.3 (19.7) (p = .105) <u>(DHI-f) Functional subscore (*M*)</u> Before 11.2 (7.7); After 9.4 (8.9) (p = .151) <u>(DHI-e) Emotional subscore (*M*)</u> Before 6.5 (6.0); After 6.2 (6.8) (p = .752) <u>(DHI-p) Physical subscore (*M*)</u> Before 11.7 (5.6); After 8.7 (6.3) (p = .019)
Pollak et al 2012 QE	N = 37; Idiopathic BPPV; 32 posterior canals 5 horizontal canals; 23 females 14 males Mean age (years) 59.2 (14.5)	Experimental: Particle Repositioning Maneouvres (as appropriate for the problem) (37) Control: Nil	1. Dizziness Handicap Inventory 2. The Illness Perception Questionnaire-Revised 3. The Intolerance of Uncertainty Scale 4. The State-Trait Anxiety Inventory Baseline 2 to 3 months later while free of vertigo	The Illness Perception Questionnaire-Revised (IPQ-R) (*M*): Before 109.3 (16.7); After 109.2 (12.1) (p = .942) The Intolerance of Uncertainty Scale (IUS) (*M*): Before 73.8 (20.6); After 70.0 (20.2) (p = .191) The State-Trait Anxiety Inventory (STAI): <u>State anxiety (STAI-S) (*M*)</u> Before 39.4 (14.2); After 38.0 (13.4) (p = .524) <u>Trait anxiety (STAI-T) (*M*)</u> Before 39.7 (11.1); After 38.5 (10.5) (p = .347) Correlations: - Belief in consequences (IPQ-R-3) of the disease with DHI (functional and emotional) (r = 0.3), and trait anxiety levels of the patients (STAI-T) (r = 0.3) (p < .05) - Belief in personal control of the condition (IPQ-R-4) with the belief in treatment control (IPQ-R-5) (r = 0.4) and the understanding of the disease (IPQ-R-6) (r = 0.3) (p < .05)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
				- Belief in treatment control (IPQ-R-5) and the understanding of the disease (IPQ-R-6) (r = 0.6) (p < .001) - Intolerance of Uncertainty Scale with DHI-emotional subscore (r = 0.3), the State and Trait Anxiety Inventory (r = 0.4) and belief in consequences of the disease (IPQ-R-3) (r = 0.3) (p < .05)
Propakis et al 2005 QE	N = 592; 302 females 290 males Mean age (years) 59 (range 18 to 84) Posterior canal: 521 (88%) Horizontal canal: 59 (10%) Anterior canal: 12 (2%)	Experimental: Epley's variant for posterior and anterior Canal BPPV (533) Barbeque roll for horizontal canal BPPV (59) Control: Nil	1. Treatment success 2. Recurrence Baseline 48 hrs after treatment 7 days Phone contact every 6 months	Treatment success: Initial Canalith Repositioning Procedure (CRP) 497/592 (84%) 2 CRP 60 (10%) 3 CRP 19 (3.1%) >3 CRP 16 (2.7%) Long term 516/592 (87%) 74% complained of instability or light-headedness for first 48-72 hrs after CRP Recurrence: 72/592 (12%) in a mean follow-up period of 46 months 23/72 were >70 years old

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Prokopakis et al 2013 QE	N = 965; 484 females 481 males Age range 18 to 87 years old Posterior canal: 849 (88%) Horizontal canal: 96 (10%) Anterior canal: 20 (2%)	Experimental: Epley's variant for posterior and anterior Canal BPPV (869) Barbeque roll for horizontal canal BPPV (96) Control: Nil	1. Treatment success 2. Recurrence Baseline 48 hrs after 7 days Phone contact every 6 months	Treatment success: Initial Canalith Repositioning Procedure (CRP) 819/965 (85%) 2 CRP 88 (9%) 3 CRP 39 (4%) >3 CRP 19 (2%) 83% complained of instability or light-headedness for first 48 hrs after CRP Recurrence: 139/965 (15.5%) in a mean follow-up of 74 months. - more in those with older age and history of head trauma or vestibular neuropathy ($p < .001$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results	
Rashad 2009 QE	N = 269; Posterior canal BPPV; Completed study (n) = 103; 58 females 45 males Mean Age (years) 48.2 (11.1)	Experimental: Epley's Manoeuvre Control: Nil	1. Subjective health (overall): - Complete cure - >50% improvement - <50% improvement - No improvement - Worse 2. Recurrence (over 5 years) Baseline 2 weeks after treatment 1 month 3 months 6 months 12 months 5 years	1-year follow-up (n = 196) and 5-year follow-up (n = 103): Subjective Health: <u>At 1 year</u> - Complete cure 95 (92%) - >50% improvement 7 (7%) - <50% improvement 1 (1%) - No improvement 0 - Worse 0 <u>At 5 years</u> - Complete cure 67 (65%) - >50% improvement 22 (21%) - <50% improvement 11 (11%) - No improvement 3 (3%) - Worse 0	Recurrence: <u>1 year</u> Rate 26/103 (25%) Time to recurrence (*M*) 3.5 (1.0) weeks <u>5 years</u> Rate 37/103 (35%) Time to recurrence (*M*) 46.3 months Independent predictor: BPPV duration ≥ 3 years or more (Odds ratio 162.5, 30.97- 852.7, $p < .001$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Ribeiro et al 2016 RCT	N = 16; Chronic BPPV (min duration 6 months without treatment) and ≥65 years old Canalith Repositioning Manoeuvre (CRM) + Vestibular Rehab = 7; 6 females 1 male Median age (years) 69 (65-78); CRM only = 7; 5 females 2 males Median age (years) 73 (65-76)	Experimental: CRM + Vestibular Rehab (7) Vestibular Rehab started 1 week (T1) after treatment Control: CRM (7)	1. Dix-Hallpike Test 2. Recurrence Baseline (T0) 1 week (T1) 5 weeks (T5) 9 weeks (T9) 13 weeks (T13)	Initial CRM efficacy for all BPPV cases based on Dix-Hallpike Test at T1: Positive: 11/14 (78.6%) Negative: 3/14 (21.4%) Recurrences (all BPPV cases) at 13 weeks: 3/14 (21.4%)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Ribeiro et al 2017 RCT	N = 16; Chronic BPPV (min duration 6 months without treatment) and ≥65 years old Canalith Repositioning Manoeuvre (CRM) + Vestibular Rehab) = 7; 6 females 1 male Median age (years) 69 (65-78); CRM only = 7; 5 females 2 males Median age (years) 73 (65-76)	Experimental: CRM + Vestibular Rehab (7) Control: CRM (7)	1. Modified Clinical Test of Sensory Integration on Balance (mCTSIB) 2. Unipedal stance 3. Limits of Stability 4. Walking across speed 5. Tandem walk 6. Dynamic Gait Index (DGI) 7. Visual Analogue Scale (dizziness intensity) 8. Dizziness Handicap Inventory Baseline (T0) 1 week (T1) 5 weeks (T5) 9 weeks (T9) 13 weeks (T13)	For CRM-only group: mCTSIB: sig. improvement ($p < .05$) seen only in the Foam eyes closed and composite scores. No sig. improvement in Unipedal stance sway velocity (eyes open/closed), Limits of Stability, Walking across speed, Tandem walk end sway and DGI ($p > .05$) Visual Analogue Scale (dizziness intensity): T0: 8 (5–10); T13: 1 (0–4) ($p < .05$) Dizziness Handicap Inventory (DHI): (All changes $p < .05$) DHI Total T0: 40 (22–70); T13: 10 (4–24) DHI Physical T0: 16 (12–24); T13: 2 (0–10) DHI Functional T0: 18 (4–30); T13: 4 (2–14) DHI Emotional T0: 10 (2–16); T13: 2 (0–4) For the experimental group, sig. improvements ($p < .05$) in static balance but no sig. difference ($p > .05$) when compared with CRM-only group. There were sig. improvements in dynamic balance ($p < .05$) within group. Sig. between group differences were seen for DGI, Tandem walk and Limits of Stability max. excursion ($p < .05$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Salvinelli et al 2004 RCT	N = 156; Mean age 74 (70-80); Posterior Canal BPPV Lempert's Manouevre = 52; 39 females 13 males Mean age (years) 73 (70–78) Flunarizine = 52; 32 females 20 males Mean age (years) 74.5 (71–80) Control = 52; 34 females 18 males Mean age (years) 75 (72–79)	Experimental: Lempert's Manoeuvre (52) Medication-Flunarizine (52) Control: No treatment (52)	1. Treatment success 2. Relapse of BPPV 3. Vestibular Disorders Activities of Daily Living – activities of living and quality of life (only in those with symptom resolution): i. Standing from sitting on the bed or chair ii. Walking in open spaces iii. Light household chores iv. Travelling around the community Baseline 6 months	Repositioning manoeuvre group only (n = 52): Treatment success: 1st session 44 (85%) 2nd session 46 (88% 3rd session 49 (94%) Relapse: 2/52 (3.8%) Vestibular Disorders Activities of Daily Living: No results reported. Only the following statement under "Results" section - "A statistically significant post-treatment improvement in activities of daily living and in quality of life was noticed ($p < .001$)."

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Sato et al 2013 QE	N = 197; Posterior canal BPPV 140 females 57 males Mean age (years) 61.5 (15.6) Etiology: Idiopathic = 152 Secondary = 40 (Head trauma = 8 Prolonged bedrest =14 Inner ear disease =18)	Experimental: Single Epley Manoeuvre without mastoid oscillation (197) Control: Nil	1. Dix-Hallpike Test 2. Time course to remission of residual positional vertigo Baseline 7 days after Epley 1 month 3 months	Negative Dix-Hallpike Test at 7 days: Idiopathic 115 (73%) Head trauma 2 (25%) Prolonged bedrest 3 (36%) Inner ear disease 10 (56%) Residual positional vertigo: 1 month → 3 months Idiopathic 6.7% → 2.3% Head trauma 50% → 25% Prolonged bedrest 41.7% → 8.3% Inner ear disease 6.1% → 2.3%

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Sekine et al 2006 RCT	N = 190; Mean age (years) 58.9 (15.4); Posterior Canal BPPV (P-BPPV) 127 Horizontal Canal BPPV (H-BPPV) 63 Modified Epley/Lempert's Manoeuvre = 96 57 females 39 males (67 P-BPPV and 29 H-BPPV) Mean age (years) 58.7 (15.5) Controls = 94; 55 females 39 males (60 P-BPPV and 34 H-BPPV); Mean age (years) 59.1 (15.3)	Experimental: P-BPPV: Modified Epley (67) H-BPPV: Lempert Manoeuvre (29) Control: No treatment (94)	1. Time course in remission of positional vertigo 2. Residual rate of positional vertigo 1 week 1 month	Residual rate of positional vertigo in successfully treated subjects: <u>Posterior canal BPPV</u> 1 week: Modified Epley 22.7% No treatment (Control) 51.7% 1 month: Modified Epley 9.7% Control 20.0% <u>Horizontal canal BPPV</u> 1 week: Lempert 21.4% Control 30.9% 1 month: Lempert 5.4% Control 7.1% (*p* = .375)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results	
Sridhar et al 2003 RCT	N = 40; Age range (years) 18 to 72 Ratio of females/males: 1:1 Particle Repositioning Manoeuvre (PRM) = 20; Median age (years) 38.5 Placebo = 20; Median age (years) 45	Experimental: PRM (20) Control: Placebo (20)	1, Symptom resolution: Grade I: complete resolution of symptoms; Grade II: partial resolution of symptoms; Grade III: no resolution or worsening of symptoms 2. Recurrence Baseline 1 week 4 weeks 3 months 6 months 9 months 12 months	For PRM group only: 1 week: Negative Dix-Hallpike Test 20 Complete resolution (of symptoms): 19 4 weeks: Negative Dix-Hallpike Test 19 Complete resolution: 19 Recurrence: 1 3 months: Negative Dix-Hallpike Test 18 Complete resolution: 19 Recurrence: 2	6 months: Negative Dix-Hallpike Test 19 Complete resolution: 19 Recurrence: 1 9 months: Negative Dix-Hallpike 17 Complete resolution: 17 Recurrence: 3 12 months: Negative Dix-Hallpike Test 18 Complete resolution: 18 Recurrence: 2

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Tan et al 2017 QE	N = 88; BPPV with hypertension (h-BPPV) group = 41; 27 females 14 males Age *M* (years) 53.4 (9.8) Idiopathic BPPV (i-BPPV) = 47; 28 females 19 males Age *M* (years) 51.64 (12.21)	Experimental: Canalith Repositioning Procedure or Barbeque Manoeuvre as appropriate (88) Control: Nil	1. Treatment success 2. Recurrence 3. Clinical characteristic differences between the 2 groups Follow-ups after diagnosis: 1 week 4 weeks 3 months	Treatment success (1 week, 4 weeks and 3 months): h-BPPV – 31 (75.6%), 39 (95.1%), 40 (97.6%) i-BPPV – 38 (80.9%), 46 (97.9%), 47 (100%) Recurrence: h-BPPV – 13 (31.7%); 6 single + 7 multiple recurrences i-BPPV – 6 (12.8%); 2 single + 4 multiple recurrences Clinical characteristic differences between the 2 groups: h-BPPV group had sig. fewer initial BPPV episodes than i-BPPV (51.2% vs 74.5%, $p = .024$) and sig. longer median episode duration compared with the i-BPPV group (60 days vs 15 days, $p = .017$). No sig. differences in age, gender, and side of lesion ($p > .05$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Wang et al 2018 Cohort Study	N = 74; Primary BPPV (Posterior Canal/Horizontal Canal/Mixed) Recurrent group = 25; 17 females 8 males Age *M* (years) 63.5 (12.3) Non-recurrent group = 42; 22 females 20 males Age *M* (years) 64.26 (12.21) Dropout: 7	Repositioning Manoeuvres as appropriate for Posterior Canal- and Horizontal Canal-BPPVs	1. Recurrence 2. Pittsburgh Sleep Quality Index (PSQI) 3. Predictors of recurrence 2 years after successful repositioning treatment	Recurrence: 25/67 (31.3%) PSQI (*Mdn*, *IQR*): Recurrent group 10 (4 - 13) Non-recurrent group 3 (1 - 7.75) No sig. differences were found in PSQI when grouped by age, gender and BPPV types ($p > .05$) Predictors of recurrence: PSQI – the only independent predictor after adjusting for age, gender, BPPV types and diabetes (*OR* 1.17, 95% CI [1.04, 1.32], $p = .0082$)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Yimtae et al 2003 RCT	N = 58; Posterior Canal BPPV Modified Canalith Repositioning Manoeuvre = 29; 25 females 4 males Mean age (years) 44.0; Unilateral 27 Bilateral 2 Medication = 29; 18 females 11 males Mean age (years) 48.0 Unilateral 28 Bilateral 1	Experimental: Modified Canalith Repositioning Procedure + Cinnarizine and instructions to take for vertigo (29) Control: Cinnarizine and instructions (29)	1. Rate of effectiveness of treatment 2. Symptom scoring - Stable/worse - Improving - No symptom 3. Time course of recovery 4. Total number of times of taking medications Baseline 1 week 4 weeks	Modified Canalith Repositioning Procedure group (n = 29): Rate of effectiveness of treatment: 75% Symptom grading at 4 weeks (post BPPV resolution) (n = 25): - Stable/worse 1/25 (4%) - Improvement 8/25 (32%) - No symptoms 16/25 (64%) Time course of recovery (negative Dix-Hallpike Test): Faster with Canalith Repositioning; median difference = 3 weeks; 95% CI [2.55%, 3.45%] (p = .02) Total no of times of taking medications: Canalith Repositioning Manoeuvre group 5.8 (2.0) vs Medication group 23.0 (4.4)

Note. QE = quasi-experimental study; RCT = randomised-controlled trial; TBI = traumatic brain injury; Sig. = significant; *M* = mean; *Mdn* = median; *IQR* = interquartile range; *SEM* = standard error of mean; *OR* = odds ratio.

3.4.3 Intervention

The repositioning manoeuvres used for treatment included Epley and Modified Epley Manoeuvres, also known as Canalith Repositioning Manoeuvre (or Procedure) (Cetin et al., 2018; Chang et al., 2008; Cohen & Kimball, 2005; Gamiz & Lopez-Escamez, 2004; Giacomini et al., 2002; R. Hoseinabadi et al., 2016; Jozefowicz-Korczynska et al., 2018; Kahraman et al., 2017; Kaur & Shamanna, 2017; Khatri et al., 2005; Y. K. Kim et al., 2005; Lopez-Escamez et al., 2005; Lopez-Escamez et al., 2003; Maslovara et al., 2017; Maslovara et al., 2012; Mendes et al., 2017; Mujeeb & Khan, 2000; Nunez et al., 2000; Ouchterlony et al., 2016; Prokopakis et al., 2013; Prokopakis et al., 2005; Rashad, 2009; Ribeiro et al., 2016; K. M. Ribeiro et al., 2017; Sato et al., 2013; Sekine et al., 2006; Sridhar et al., 2003; J. Tan et al., 2017; Yimtae et al., 2003), the Semont or Liberatory Manoeuvre (Cohen & Kimball, 2005; Di Girolamo et al., 1998; L. Kollén et al., 2006; Salvinelli et al., 2004), and the Lempert or Barbeque Manoeuvre (Kahraman et al., 2017; Prokopakis et al., 2013; Prokopakis et al., 2005; Sekine et al., 2006; J. Tan et al., 2017). Three studies did not specify the repositioning manoeuvres used (E. J. Kim et al., 2015; Pollak et al., 2012; Wang et al., 2018).

3.4.4 Outcomes

Positional tests were widely used in the studies to determine treatment success. Subjective rating of dizziness/vertigo/recovery (Chang et al., 2008; Cohen & Kimball, 2005; Kaur & Shamanna, 2017; Khatri et al., 2005; Y. K. Kim et al., 2005; L. Kollén et al., 2006; Ouchterlony et al., 2016; K. M. Ribeiro et al., 2017; Sekine et al., 2006; Sridhar et al., 2003; Yimtae et al., 2003) and recurrence (Cetin et al., 2018; Jozefowicz-Korczynska et al., 2018; Y. K. Kim et al., 2005; Maslovara et al., 2017; Mendes et al., 2017; Mujeeb & Khan, 2000; Nunez et al., 2000; Prokopakis et al., 2013; Prokopakis et al., 2005; Rashad, 2009; Ribeiro et al., 2016; Salvinelli et al., 2004; Sridhar et al., 2003; J. Tan et al., 2017; Wang et al., 2018) were also commonly reported. The other outcomes used included the Dizziness Handicap Inventory (R. Hoseinabadi et al., 2016; Kaur & Shamanna, 2017; Maslovara et al., 2012; Ouchterlony et al., 2016; Pollak et al., 2012; K. M. Ribeiro et al., 2017), the 36-item Short Form Survey (SF36) (Gamiz & Lopez-Escamez, 2004; Lopez-Escamez et al., 2005; Lopez-Escamez et al., 2003; Maslovara et al., 2012; Ouchterlony et al., 2016), residual symptoms/time to remission of symptoms (Kahraman et al., 2017; L.

Kollén et al., 2006; Prokopakis et al., 2013; Prokopakis et al., 2005; Sato et al., 2013; Sekine et al., 2006), gait and balance measures (Chang et al., 2008; Cohen & Kimball, 2005; Di Girolamo et al., 1998; Giacomini et al., 2002; L. Kollén et al., 2006; K. M. Ribeiro et al., 2017), dizziness frequency (Cohen & Kimball, 2005), psycho-emotional measures (anxiety, depression, self-perception) (Kahraman et al., 2017; Maslovara et al., 2012; Pollak et al., 2012), the Vestibular Evoked Myogenic Potential (E. J. Kim et al., 2015; Mendes et al., 2017), self-report questionnaires on general health and level of disability (L. Kollén et al., 2006; Salvinelli et al., 2004), Vitamin D and Calcium serum levels (Maslovara et al., 2017), and sleep quality (Wang et al., 2018).

3.4.5 Methodological quality (see Tables 3.3a, 3.3b and 3.3c)

Of the 11 randomised-controlled trials, only four scored seven and above, out of a total possible 13 points (Cetin et al., 2018; Chang et al., 2008; Ribeiro et al., 2016; K. M. Ribeiro et al., 2017). The scores ranged from 3/13 to 8/13 with a median score of 6/13. None of the RCTs were rated as having blinding of the assessors or treating personnel, or for the use of intention-to-treat analysis. Most studies performed poorly on the randomization process, allocation concealment, reliability of outcomes measurement, and power calculations. Ten of the 23 quasi-experimental studies scored five and above, out of a total possible nine points (Jozefowicz-Korczynska et al., 2018; Kahraman et al., 2017; E. J. Kim et al., 2015; L. Kollén et al., 2006; Mendes et al., 2017; Mujeeb & Khan, 2000; Prokopakis et al., 2013; Prokopakis et al., 2005; Rashad, 2009; J. Tan et al., 2017). The scores ranged from 2/9 to 6/9 with a median of 4/9. The lack of reliability in the outcome measurements was a common problem. Studies also performed poorly on the following criteria: ensuring similar other exposure/treatment, having a control group, having adequate follow-up, and performing power calculations. The only cohort study (Wang et al., 2018) scored 5/12 and lacked clarity in the criteria: reliability/validity of exposure and outcome measurements, adequate follow-up, and appropriate statistical analysis.

Table 3.3a. Quality appraisal of randomised controlled trials using JBI Critical Appraisal Tools

	Cetin et al 2018	Chang et al 2008	Cohen and Kimball 2005	Kaur and Shamanna 2017	Maslovara et al 2012	Ribeiro et al 2016	Ribeiro et al 2017	Salvinelli et al 2004	Sekine et al 2006	Sridhar et al 2003	Yimtae et al 2003
True randomisation	X	Unclear	Unclear	Unclear	Unclear	√	√	X	X	√	Unclear
Allocation concealment	Unclear	√	Unclear	Unclear	Unclear	√	√	Unclear	X	Unclear	Unclear
Similar baseline characteristics	√	√	Unclear	√	√	√	√	Unclear	√	X	√
Blinding - Participants	√	X	X	√	X	X	X	X	X	√	Unclear
Blinding - Treating staff	Unclear	X	X	Unclear	Unclear	X	X	Unclear	X	Unclear	Unclear
Blinding - Assessors	Unclear	√	√	Unclear	Unclear	√	√	Unclear	X	Unclear	√
Similar OTHER treatment[#]	√	Unclear	√	X	√	√	√	√	Unclear	Unclear	√
Adequate follow-up	√	√	√	Unclear	Unclear	√	√	√	Unclear	√	X
Participant analysed in assigned group*	Unclear	Unclear	No	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Outcomes measured similarly throughout	√	√	√	√	√	√	√	√	√	√	√
Outcomes measured reliably	Unclear	√	Unclear	Unclear	X	Unclear	Unclear	X	X	X	X
Appropriate statistics analysis	√	X	√	X	X	X	X	√	X	√	√
Design appropriate/Deviation	√	√	X	√	√	√	√	√	√	√	√
Total score	7/13	7/13	5/13	4/13	4/13	8/13	8/13	5/13	3/13	6/13	6/13

Note. √ = Yes; X = No; NA = Not applicable; [#]Use or control of use of vestibular suppressants rated as "Unclear" if not clearly stated (excluding studies on medications) unless other factors assumed greater significance; *Intention-to-treat (ITT): considered present when clearly stated.

Table 3.3b. Quality appraisal of quasi-experimental studies using JBI Critical Appraisal Tools

	Gamiz and Lopez-Escamez 2004	Giacomini et al 2002	Girolamo et al 1998	Hoseinabadi et al 2016	Jozefowicz-Korczynska et al 2018	Kahraman et al 2017	Khatri et al 2005	Kim et al 2005	Kim et al 2015	Kollen et al 2006	Lopez-Escamez et al 2003
Clear cause and effect	√	√	√	√	√	√	√	√	√	√	√
Similar participant characteristics in comparison groups	√	Unclear	Unclear	Unclear	√	√	Unclear	√	√	√	√
Similar OTHER treatment/exposure[#]	Unclear	Unclear	Unclear	Unclear	Unclear	√	X	Unclear	Unclear	Unclear	Unclear
Control group	X	√	√	X	X	√	X	X	√	X	X
Multiple measurements pre- and post-treatment/exposure	√	√	√	√	√	√	√	√	√	√	√
Adequate follow-up	X	Unclear	Unclear	Unclear	√	Unclear	Unclear	Unclear	X	√	X
Outcomes measured similarly throughout	√	√	√	√	√	√	√	√	√	√	√
Outcomes measured reliably	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Appropriate statistical analysis	X	X	X	Unclear	X	X	X	X	X	X	X
Total score	4/9	4/9	4/9	3/9	5/9	6/9	3/9	4/9	5/9	5/9	4/9

Note. √ = Yes; X = No; NA = Not applicable; [#]Use or control of use of vestibular suppressants rated as “Unclear” if not clearly stated (excluding studies on medications) unless other factors assumed greater significance.

Table 3.3b. Quality appraisal of quasi-experimental studies using JBI Critical Appraisal Tools (continued)

	Lopez-Escamez et al 2005	Maslovara et al 2017	Mendes et al 2017	Mujeeb and Khan 2000	Nunez et al 2000	Ouchterlony et al 2016	Pollak et al 2012	Prokopakis et al 2005	Prokopakis et al 2013	Rashad et al 2009	Sato et al 2013	Tan et al 2017
Clear cause and effect	√	√	√	√	√	√	√	√	√	√	√	√
Similar participant characteristics in comparison groups	√	√	√	√	√	X	√	√	√	√	X	X
Similar OTHER treatment/exposure	Unclear	Unclear	Unclear	√	X	Unclear	Unclear	X	X	Unclear	Unclear	Unclear
Control group	X	X	X	X	X	√	X	X	X	X	X	√
Multiple measurements pre- and post-treatment/exposure	√	√	√	√	X	√	√	√	√	√	√	√
Adequate follow-up	X	Unclear	√	√	X	X	Unclear	√	X	X	Unclear	√
Outcomes measured similarly throughout	√	√	√	√	X	√	√	√	√	√	√	√
Outcomes measured reliably	X	Unclear	Unclear	X	X	X	X	X	X	X	Unclear	Unclear
Appropriate statistical analysis	X	X	X	X	X	X	X	√	√	√	√	X
Total score	4/9	4/9	5/9	6/9	2/9	4/9	4/9	6/9	5/9	5/9	4/9	5/9

Note. √ = Yes; X = No; NA = Not applicable; [#]Use or control of use of vestibular suppressants rated as "Unclear" if not clearly stated (excluding studies on medications) unless other factors assumed greater significance.

Table 3.3c. Quality appraisal of cohort studies using JBI Critical Appraisal Tools

	Groups similar and from same population	Similar measurement for exposures for group allocation	Measurement of exposure valid and reliable	Confounding factors identified	Strategies to deal with confounding factors	Participants free of outcome at start	Outcomes measurement reliable and valid	Follow-up reported and sufficient	Follow-up complete. If not, adequate reason given	Used strategies to address incomplete follow-ups	Appropriate stat analysis	Total score
Wang et al 2018	√	√	Unclear	√	√	X	Unclear	√	X	X	Unclear	5/11

3.4.6 Results of individual studies

The overall efficacy of repositioning manoeuvres ranged from 70% to 100% as assessed by the positional tests. Initial treatment efficacy ranged from 61% to 87% (Gamiz & Lopez-Escamez, 2004; R. Hoseinabadi et al., 2016; Khatri et al., 2005; Lopez-Escamez et al., 2005; Lopez-Escamez et al., 2003; Mujeeb & Khan, 2000; Nunez et al., 2000; Prokopakis et al., 2013; Prokopakis et al., 2005). However, it was reported to be lower (21% - 47%) in some studies (Y. K. Kim et al., 2005; L. Kollén et al., 2006; Ribeiro et al., 2016). One study reported 73% efficacy rate for BPPV with idiopathic etiology but 25-56% for BPPV secondary to head trauma, prolonged bedrest, and inner ear disease (Sato et al., 2013).

At one-month, significant improvement in vertigo/dizziness was reported (Chang et al., 2008; Cohen & Kimball, 2005; Khatri et al., 2005; L. Kollén et al., 2006; Ouchterlony et al., 2016; Rashad, 2009; K. M. Ribeiro et al., 2017; Sridhar et al., 2003; Yimtae et al., 2003). Nevertheless, some reported incomplete resolution of symptoms despite negative positional tests (Khatri et al., 2005; Yimtae et al., 2003). Sekine et al (2006) and Sato et al (Sato et al., 2013) reported residual vertigo in 5-10% and 6-50% of participants with BPPV, respectively. Another study (Kahraman et al., 2017) found the mean time to correction of vertigo and imbalance were 33 and 25 days respectively while mean time to BPPV resolution was 11 days. Improvement in static balance, Sensory Organisation Test and Dynamic Gait Index were reported (Chang et al., 2008; Di Girolamo et al., 1998; K. M. Ribeiro et al., 2017). Less favourable results were reported for dynamic balance and balance with eyes closed (Chang et al., 2008; L. Kollén et al., 2006; K. M. Ribeiro et al., 2017). Quality of life (SF36) and the Dizziness Handicap Inventory scores also improved (Gamiz & Lopez-Escamez, 2004; Lopez-Escamez et al., 2005; Lopez-Escamez et al., 2003; Ouchterlony et al., 2016). However, it was found that participants with concomitant otolith dysfunction continued to have significantly higher Dizziness Handicap Inventory scores, compared to those without otolith problems, one month after successful treatment (R. Hoseinabadi et al., 2016).

Beyond one-month, despite BPPV resolution, residual vertigo/dizziness and feeling of unsteadiness were reported (L. Kollén et al., 2006; Sato et al., 2013). At three months, 2.3-25.0% of participants with BPPV of various etiologies still complained of residual vertigo/dizziness (Sato et al., 2013). Kollen et al (2006) reported 52.9% of participants continued to feel unsteady at 12 months. The

Dizziness Handicap Inventory scores improved significantly from baseline in four (R. Hoseinabadi et al., 2016; Maslovara et al., 2012; Ouchterlony et al., 2016; K. M. Ribeiro et al., 2017) out of five studies. Quality of life (SF36) scores showed improvements with repositioning manoeuvres in most domains except Role limitation due to emotional problems (Lopez-Escamez et al., 2005) and the mental health component (Ouchterlony et al., 2016). Compared with healthy controls, participants with BPPV had significantly higher anxiety levels (Kahraman et al., 2017; Maslovara et al., 2012). Negative emotional beliefs, anxiety, and perception persisted even after these participants were “cleared” of BPPV for three months (i.e., resolution of signs and symptoms on positional tests) (Kahraman et al., 2017; Maslovara et al., 2012; Pollak et al., 2012). Two studies (E. J. Kim et al., 2015; Mendes et al., 2017) from the older adult group investigated otolithic function using the Vestibular Evoked Myogenic Potential (VEMP) test. One study (E. J. Kim et al., 2015) found that participants with BPPV had a higher proportion of abnormal VEMP results, in both affected and non-affected ears, compared with healthy controls. Two months after successful treatment, there were no significant improvements in the VEMP for both ears. However, Mendes et al (2017) found improvements in the Ocular VEMP amplitude and asymmetrical ratio (AR) parameters after treatment, with AR being the only significant predictor of recurrence (77.8% sensitivity, 94.9% specificity, $p = .002$).

Improvements in outcomes were reported across various studies, of which most did not include a comparison control group. In this paper, final results were tabulated and compared with age-matched or close to age-matched data (Bohannon, 1997; Choy, Brauer, & Nitz, 2003; Davalos-Bichara & Agrawal, 2014; Di Girolamo et al., 1998; Gamiz & Lopez-Escamez, 2004; Garratt & Stavem, 2017; Gerolimatos & Edelstein, 2012; Giacomini et al., 2002; Kahraman et al., 2017; E. J. Kim et al., 2015; Lim & Lee, 2012; Lopez-Escamez et al., 2005; Lopez-Escamez et al., 2003; Maslovara et al., 2012; Nyenhuis, Yamamoto, Luchetta, Terrien, & Parmentier, 1999; Ouchterlony et al., 2016; Park & Jung, 2018; Schmidheiny, Swanenburg, Straumann, de Bruin, & Knols, 2015; Vereeck, Wuyts, Truijen, & Van de Heyning, 2008) (see Table 3.4). Both younger and older adult groups experienced residual dizziness, recurrences, and less than optimal improvements in various outcomes when compared with normative/comparison data. These outcomes included the Dizziness Handicap Inventory, Dynamic Gait Index and other gait

measures, the Sensory Organisation Test, dynamic balance measures, mental health (anxiety) and quality of life.

Recurrence rates ranged from 4% to 18% at six months (Khatri et al., 2005; Y. K. Kim et al., 2005; Salvinelli et al., 2004; Sridhar et al., 2003). Prokopakis et al (2013) reported 15.5% recurrence rate in a mean follow-up period of 74 months. The authors associated the recurrence with older age and history of head trauma or vestibular neuropathy ($p < .001$). Rashad (2009) reported a higher recurrence rate of 35% at 5 years, with a similar association with increasing age (≥ 40 years old), but the independent predictor of recurrence was disease duration of three years or more at the time of initial treatment.

3.4.7 Comparison of outcomes between older and younger adult groups: Meta-analysis

From the numerous outcomes discussed, we managed to pool data to perform meta-analysis for the following: The Dizziness Handicap Inventory (DHI), static and dynamic balance and recurrence. As the focus was mainly on groups treated only with repositioning manoeuvres and different scales were often used for a single outcome, the standardised mean differences for DHI, and static and dynamic balance were calculated and pooled using the Generic Inverse Variance method available in the Review Manager software (Version 5.3) (2014). Median values were converted to mean (standard deviation) using the median value, minimum and maximum range, and the sample size (n) (Hozo, Djulbegovic, & Hozo, 2005; Lowry, 1998-2018).

For DHI, results were pooled from four studies (R. Hoseinabadi et al., 2016; Lopez-Escamez et al., 2003; Maslovara et al., 2012; Pollak et al., 2012) for the younger adult group and from two studies for the older adult group (Gamiz & Lopez-Escamez, 2004; K. M. Ribeiro et al., 2017)(see Figure 3.2a). The results showed that the younger adult group had more improvement in the DHI scores (-1.84, 95% CI [-3.75, 0.07]) compared with the older adult group (-1.00, -4.12 to 2.12). Compared with the younger group, older adults perceived less change in their dizziness-related handicap despite improvement in the BPPV status.

Table 3.4. Comparison of treatment outcomes for younger and older adult groups with normative/comparison data

<table>
<tr><th></th><th colspan="7">Results as at study completion</th><th>Normative/Comparison data</th></tr>
<tr><td>Residual symptoms</td><td colspan="5">Younger adults</td><td colspan="2">Older adults</td><td>Not applicable</td></tr>
<tr><td></td><td>Unknown age group:

At one-month, negative Dix-Hallpike test 87.1%
Complete resolution of symptoms 85.5%
(Khatri et al., 2005) (Khatri et al., 2005)</td><td>Mean time (days) to:
- Negative positional tests: 11.16 (8.60)
- Correction of vertigo: 32.69 (24.68)
- Correction of unsteadiness: 25.41 (28.60)
(Kahraman et al., 2017)</td><td>Unsteadiness ↓ sig. during the initial few months after treatment but remained the same after 12 months. 9/17 subjects still complained of unsteadiness at end of study.
(L. Kollén et al., 2006)</td><td>Residual rate of positional vertigo in successfully treated BPPV cases at 1 month:
Posterior canal BPPV 9.7%
Horizontal canal BPPV 5.4%
(Sekine et al., 2006)</td><td>74% and 83% complained of instability or light-headedness for first 48-72 hours after Canalith Repositioning Procedure (Prokopakis et al., 2013; Prokopakis et al., 2005)</td><td>Symptom grading (4 weeks post BPPV resolution):
- Stable/worse 4%
- Improvement 32%
- No symptom 64%
(Yimtae et al., 2003)</td><td colspan="2">Residual positional vertigo (at 1/3 months):

Idiopathic 6.7% / 2.3%

Head trauma 50% / 25%

Prolonged bedrest 41.7% / 8.3%

Inner ear disease ≈ 6.1% / 2.3%

(Sato et al., 2013)</td></tr>
<tr><td>Dizziness Handicap Inventory (Total score 100)</td><td colspan="5">Younger adults</td><td colspan="2">Older adults</td><td>5.6 (11.2)
(Davalos-Bichara & Agrawal, 2014)(Data on healthy older adults, mean age 77.2 (6.1) years old)</td></tr>
<tr><td></td><td colspan="2">With otolith problem 9.20 (8.16)
Without otolith problem 4.13 (5.26)
(R. Hoseinabadi et al., 2016)</td><td>*Mdn* 10 (8.0 - 22.0)
(Maslovara et al., 2012)</td><td>17.8 (5.9)
(Ouchterlony et al., 2016)</td><td>24.3 (19.7)
(Pollak et al., 2012)</td><td colspan="2">*Mdn* 10 (4 - 24) (K. M. Ribeiro et al., 2017)</td></tr>
<tr><td>36-Item Short Form Survey (SF36)</td><td colspan="7">Improvements and normalization reported in most domains.
However, domain Role Emotional (RE) consistently did not improve and normalize in the following 3 studies:

- Older adults (Gamiz & Lopez-Escamez, 2004)

- Younger adults (Lopez-Escamez et al., 2005; Lopez-Escamez et al., 2003)</td><td>The Spanish Population normative data – set as mean of 0 with data of subjects with BPPV plotted in same graph for comparison
(Gamiz & Lopez-Escamez, 2004; Lopez-Escamez et al., 2005; Lopez-Escamez et al., 2003)(Intra-study)</td></tr>
<tr><td></td><td colspan="7"><u>Younger adults</u>

Total score: 72.96
(Maslovara et al., 2012)

Component scores:
Physical 44.5 (1.9); Mental Health ≈ 39
(Ouchterlony et al., 2016)</td><td>Total score: 86.42
(Maslovara et al., 2012)(intra-study normal controls)

Component scores:
Physical 43.6 (2.8); Mental Health 46.7 (4.1)
(Ouchterlony et al., 2016)(Data on Traumatic Brain Injury with no dizziness group)

Physical 50.8 – 53.6; Mental Health 50.9 – 52.6 (Garratt & Stavem, 2017) (Normative data for the Norwegian population aged 20 to ≤ 50 years old)</td></tr>
</table>

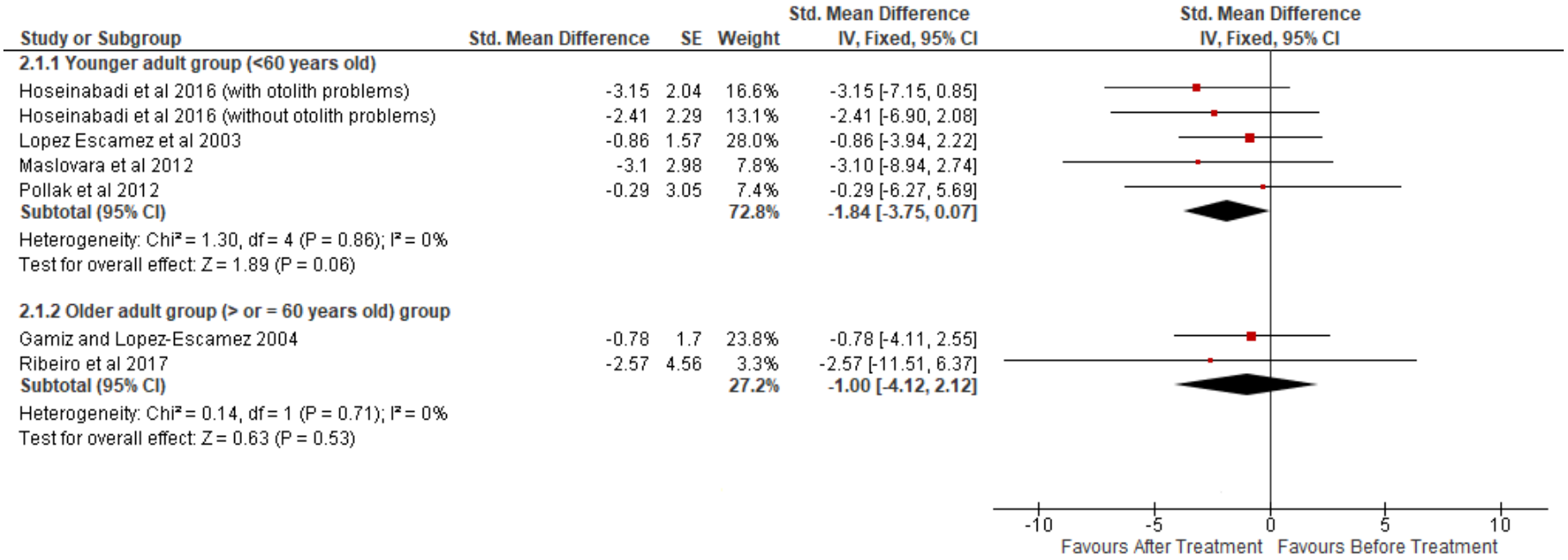
	Results as at study completion		Normative/Comparison data
Mental Health	No data on older adults were available. Younger adults only: The State-Trait Anxiety Inventory State anxiety 38.0 (13.4); Trait anxiety 38.5 (10.5) (Pollak et al., 2012) Intolerance of Uncertainty Scale 70.0 (20.2) (Pollak et al., 2012)	Beck Anxiety Inventory 4.93 (7.00) (p = .031) Panic Agoraphobia Scale 6.56 (6.33) (p < .001) (Kahraman et al., 2017) The Hospital Anxiety and Depression Scale Anxiety: 0.94 (0.21); Depression: 1.32 (0.12) (Maslovara et al., 2012)	The State-Trait Anxiety Inventory State anxiety 32.9 (11.1); Trait anxiety 35.6 (9.9) (Nyenhuis et al., 1999)(data on healthy adults with mean age 44.0 (18.4)) Intolerance of Uncertainty Scale 18 - 30 years old 63.55 (22.06); ≥ 60yo 52.15 (18.87) (Gerolimatos & Edelstein, 2012)(data on young and older adults from community) Beck Anxiety Inventory 2.25 (1.85) Panic Agoraphobia Scale 0.25 (1.41) (Kahraman et al., 2017)(Intra-study) The Hospital Anxiety and Depression Scale Anxiety: 0.88 (0.09); Depression 1.31 (0.09) (Maslovara et al., 2012)(Intra-study)
Modified Clinical Test of Sensory Integration of Balance or parts of it - Sway velocity	Younger adults Firm eyes open 5.4 (2.9); eyes closed 9.6 (3.0) (p > .05) (Giacomini et al., 2002)	Older adults Firm eyes open 0.3 (0.1–0.4) (*Mdn*, range) Firm eyes closed 0.3 (0.2–0.4) Foam eyes open 0.7 (0.3–1.2) Foam eyes closed 1.0 (0.5–6.0) (K. M. Ribeiro et al., 2017)	Firm eyes open 4.53 (2.3); eyes closed 8.5 (1.3) (Giacomini et al., 2002)(intra-study) Firm with eyes open 6th decade: 0.213 (0.24) 7th decade: 0.211 (0.09) Firm with eyes closed 6th decade: 0.270 (0.13) 7th decade: 0.325 (0.17) Foam with eyes open 6th decade: 0.656 (0.26) 7th decade: 0.932 (0.75) Foam with eyes closed 6th decade: 2.76 (1.28) 7th decade: 4.04 (1.63) (Choy et al., 2003)(data on females aged 20 - 80 years old)
Standing on one leg	Younger adults Sway velocities (deg/s) Eyes open: 0.58 (0.16) Eyes closed: 9.43 (3.49) (Chang et al., 2008)	Time (secs) Eyes closed 11 (10) (L. Kollén et al., 2006)	Sway velocities (deg/s) Eyes open (right leg) 4th decade: 0.600 (0.16); 5th decade: 1.130 (1.63); 6th decade: 2.350 (3.25); 7th decade: 5.830 (4.37) Eyes closed (right leg) 4th decade: 6.630 (4.03); 5th decade: 8.760 (3.47); 6th decade: 10.520 (2.61); 7th decade: 11.660 (1.46)

	Results as at study completion		Normative/Comparison data
	Older adults Eyes open: 8.5 (1.0–12.0) (*Mdn*, range) Eyes closed: 12.0 (12.0-12.0) (K. M. Ribeiro et al., 2017)		(Choy et al., 2003)(data on females aged 20 - 80 years old) Time (secs) with eyes closed 4th decade 27.48 (6.48); 5th decade 21.77 (9.09); 6th decade 19.92 (9.81) (Vereeck et al., 2008)(data on adults aged ≥ 20 years old)
Sensory Organisation Test (SOT) Younger adults (Di Girolamo et al., 1998)	Composite 72.0 (7.6) } Somatosensory 100.0 (10.0) } Visual 82.0 (18.0) } sig. different from results of control subjects ($p < .05$) for all scores except for Somatosensory Vestibular 67.0 (17.0) } Preferential 89.0 (9.0) }		Composite 80.0 (3.5) Somatosensory 98.0 (1.0) Visual 89.0 (6.0) Vestibular 71.0 (7.0) Preferential 100.0 (4.0) (Intra-study)
Dynamic Gait Index (Total score 24)	Younger adults 22.5 (1.4) (Chang et al., 2008) (Chang et al., 2008)	Older adults *Mdn* 20 (17–22) (K. M. Ribeiro et al., 2017)	4th decade: 24 (0.2); 5th decade: 23.9 (0.4); 6th decade: 23.9 (0.4); 7th decade: 23.2 (0.9) (Vereeck et al., 2008) (Vereeck et al., 2008)(data on adults aged ≥20 years old)
Tandem walk end sway velocity (deg/s)	3.90 (1.39) (Chang et al., 2008)	*Mdn* 5.9 (range 5.1 – 6.5) (K. M. Ribeiro et al., 2017)	4.26 (1.34) (Park & Jung, 2018) (data on healthy adults, mean age 52.2 (9.6) years old) 3.6 (1.2) (Lim & Lee, 2012)(data on healthy females with mean age 64.8 (4.1) years old)
Walking Younger adults (L. Kollén et al., 2006)	Speed (m/s) Normal speed walking 1.25 (0.21) Walking with horizontal head turns 1.2 (0.2) Walking with vertical head turns 1.2 (0.19)	Step length (m) Walk with horizontal head turns 0.66 Walk with vertical head turns 0.70 (L. Kollén et al., 2006)	Normal walking speed (m/s) 1.4 (Bohannon, 1997; Schmidheiny et al., 2015) Walking with horizontal head turns: Speed (m/s) 1.3 (0.2); Step length (m) 0.71 Walking with vertical head turns: Speed (m/s) 1.3 (0.2); Step length (m) 0.72 (Schmidheiny et al., 2015)(data on healthy adults with mean age 44 (13) years old, range 25 - 70)

	Results as at study completion	Normative/Comparison data
Recurrences	Younger adults 28% (over 18 months) (Cetin et al., 2018) 12.5% (over 2 years) (Jozefowicz-Korczynska et al., 2018) 3.3% (over 4 weeks) (Kaur & Shamanna, 2017) 13% for anterior BPPV; 10% for posterior/lateral BPPV (mean follow-up 6.8 months) (Y. K. Kim et al., 2005) 7.5% (over 12 months) (Lopez-Escamez et al., 2005) 14.2% within first 3 weeks (Mujeeb & Khan, 2000) 12% (mean follow-up of 46 months) (Prokopakis et al., 2005) 15.5% (mean follow-up of 74 months) (Prokopakis et al., 2013) 25% at 1 year; 35% at 5 years (Rashad, 2009) 21.6% (over 3 months) (J. Tan et al., 2017) Older adults 16% (over 6 months) (Maslovara et al., 2017) 18.8% (over 6 months) (Mendes et al., 2017) 26.8% (mean follow-up 26 months) (Nunez et al., 2000) 21.4% (over 13 weeks) (K. M. Ribeiro et al., 2017) 3.8% (over 6 months) (Salvinelli et al., 2004) 31.3% (over 2 years) (Wang et al., 2018) Unknown age group 18.4% at 6 months (Khatri et al., 2005)	Not applicable

Note. *Mdn* = median; *IQR* = inter-quartile range

Figure 3.2a. Forest plot showing results of studies in the younger (< 60 years old) and older (≥ 60 years old) groups for the change in Dizziness Handicap Inventory scores between baseline and final assessments post repositioning manoeuvres



Static balance was pooled from the sway velocity results of standing on firm surface and foam, and standing on one leg, with eyes open and closed for each condition. For the younger adult group, there were only two relevant studies (Chang et al., 2008; Giacomini et al., 2002). However, for the older adult group, the results for the various test conditions were pooled from one single study (K. M. Ribeiro et al., 2017) as no other studies in the older adult group had the relevant data. A decrease in the sway velocity (negative change) indicated improvement in balance. Both groups appeared to have comparable improvements in static standing balance (older adult group: -0.70 (-1.25 to -0.14) and younger adult group: -0.53 (-0.62 to -0.43) (see Figure 3.2b). The heterogeneity (I^2 98%, $p < .001$) in the older adult group results was possibly due to (i) no change at all in Single leg standing with eyes closed from baseline; and (ii) wide confidential intervals that crossed the line of null effect for Standing on foam with eyes closed and Single leg standing with eyes open. Dynamic standing balance was pooled from results of the Dynamic Gait Index (DGI) and the Tandem gait end sway velocity. Only results of one study from each age group (Chang et al., 2008; K. M. Ribeiro et al., 2017) were pooled as no other studies were relevant. The timeline for the younger adult group was at 4 weeks as there was no follow-up beyond that. The older adult group results were pooled at 5 weeks (to be comparable with that of the younger group) and at 13 weeks. The change in DGI scores was reversed in direction to align with the directional changes of the Tandem gait end sway velocity. From the results, the younger adults group experienced larger improvement (-0.91, -1.60 to -0.23) at short term when compared with the older group (-0.18, -1.54 to 1.17) (see Figure 3.2b). However, the older adult group seemed to continue to experience improvement (effect estimate improved to 1.11) at 13 weeks, although this improvement did not reach statistical significance.

The proportions for recurrence for studies with 6-24 months follow-up time were pooled using the meta-analysis of proportions function available in the MedCalc software (Version 18.10.2) (Freeman & Tukey, 1950; 2018). This timeline was chosen to optimize the number of studies pooled as the follow-up time varied widely across the studies. The pooled recurrence proportion for older adults was 20.5% (I^2 80.7%, random effect, 95% CI [11.3, 31.7]), similar to that of the younger adult group at 18.8% (I^2 66.2%, random effect, 95% CI [11.5, 27.4]) (see Figures 3.3a and 3.3b).

Figure 3.2b. Forest plot showing results of studies in the younger and older adult groups for changes in static and dynamic balance after repositioning manoeuvres

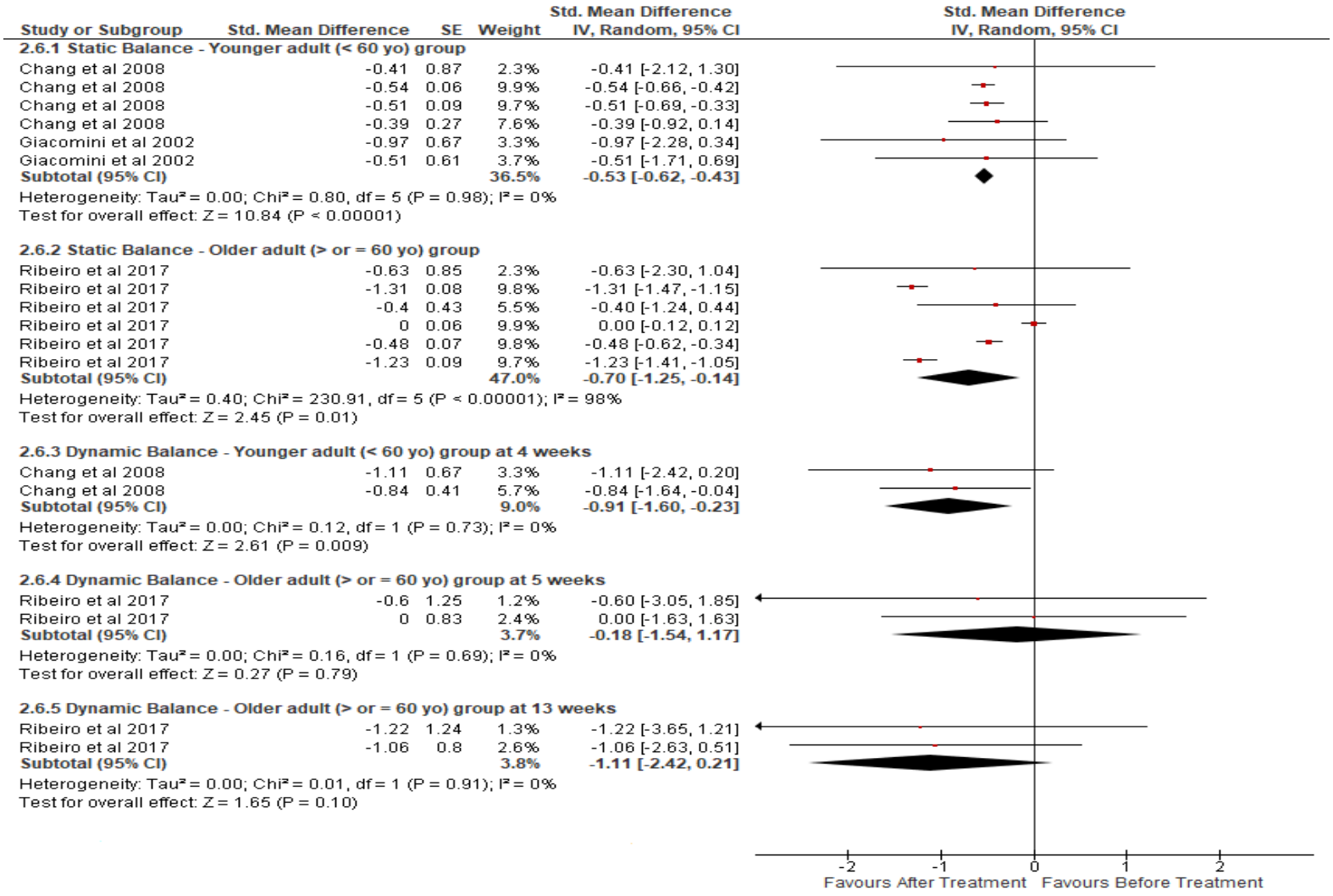


Figure 3.3a. Forest plot showing results of studies in the younger adult (<60 years old) group for recurrence

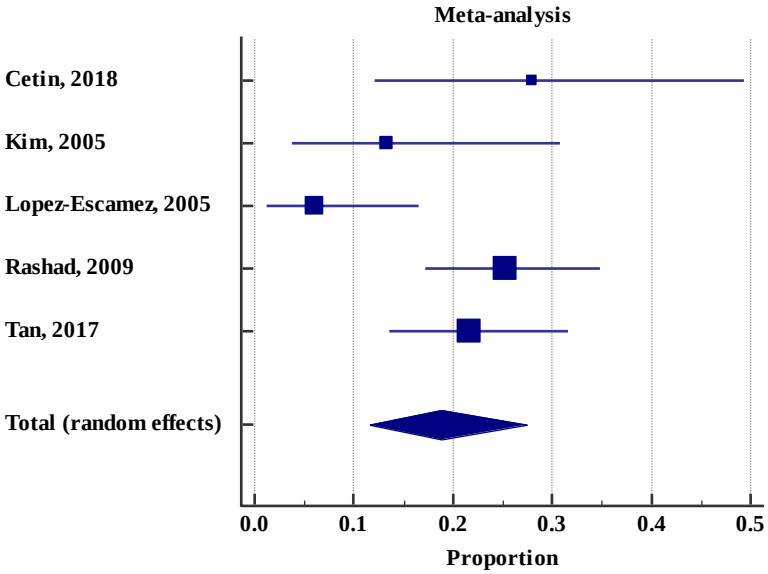
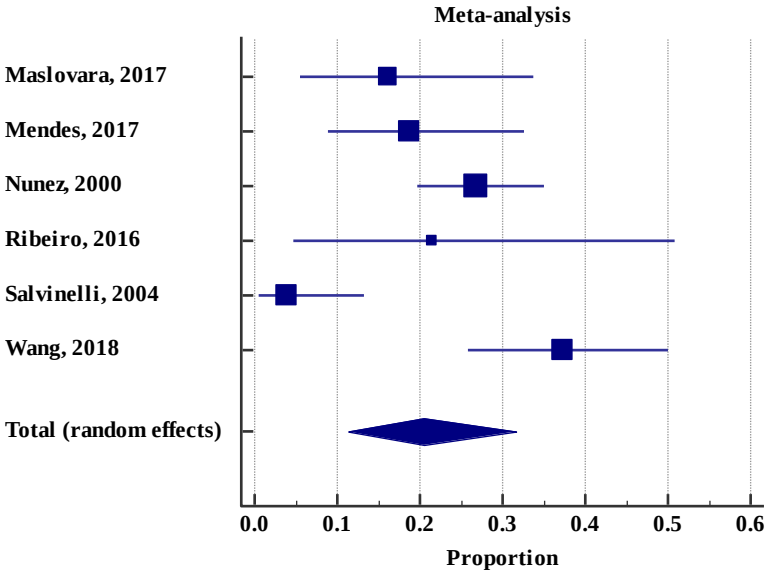


Figure 3.3b. Forest plot showing results of studies in the older adult (≥ 60 years old) group for recurrence



3.5 Discussion

The efficacy of repositioning manoeuvres is well established in the literature and this review revealed similar findings. However, it is important to note that efficacy has most commonly been measured using positional tests and subjective dizziness/vertigo reports. In addition to these important outcomes, this review also identified physical, functional, and psycho-emotional impairments that persisted one month or more after the initial repositioning treatment.

Residual dizziness and unsteadiness were reported by several studies in this review. However, these studies did not further establish associative factors to the problem. A recent review on residual dizziness/unsteadiness after physical treatment for BPPV discussed the possible causes as persistent debris in the canal, delayed vestibular adaptation after treatment, other vestibular dysfunctions, duration of vertigo, anxiety and utricular/otolithic dysfunction (Giommetti et al., 2017). It also reported a prevalence of 31 - 61% with older adults commonly affected. This contrasted with the prevalence range (2 - 52%) and the lack of evidence of residual dizziness in older adults reported in this systematic review. This may be explained by the dearth of relevant studies in the older adult group, hence rendering the findings on residual dizziness in this systematic review inconclusive.

Contrary to some reports (Kao et al., 2009; Prokopakis et al., 2013), recurrence proportions were found to be similar between the younger and older adult groups in this systematic review. One major factor could be the lack of exclusively younger or older adult group studies in this systematic review resulting in the lack of significant differences in recurrence. The follow-up time also varied widely across the studies. Better quality studies with clearer age-differentiated groups and homogenous follow-up timelines are required for conclusive results.

The clinical implications of this review's findings are that, apart from positional tests, patients with BPPV should be further assessed for residual symptoms, and gait and balance deficits. Treatment should be prescribed for domains where assessment findings remain subnormal post successful repositioning. Few studies had investigated the mental health impact of BPPV, but the results were consistent: anxiety and negative emotions were frequently present and persisted in many people with BPPV. Hence

these patients should also be monitored for anxiety and negative emotions/moods and be offered timely help if necessary.

Older adults had poorer dynamic balance recovery and higher level of perceived handicap, despite repositioning manoeuvres. Failure to address these issues might result in further debilitation and undesired consequences such as falls and functional decline. Falls were not investigated in any studies. Older adults with BPPV have increased falls risk due to impaired balance, especially under vision denied- and altered proprioceptive- conditions (Chang, Hsu, Yang, & Wang, 2006; Oliva Domínguez et al., 2005), and vertigo (Ganança et al., 2006). Additionally, some experienced residual balance impairments three months after initial treatment (K. M. Ribeiro et al., 2017). It is crucial that falls measures be incorporated into future research and management for older adults with BPPV.

Limitations

Several studies with potentially relevant outcomes were excluded as they did not fully meet the inclusion criteria. Short term recovery from BPPV have been widely reported. However, the focus of this review was on findings beyond one month and beyond recovery based solely on positional tests. In general, moderate heterogeneity existed across studies in the areas of outcomes used, follow-up timelines, treatment frequency and dosage, and methodological quality. Meta-analysis could only be performed for some outcomes from a limited number of studies. Research methodology in this area was of low to medium quality, hence limiting the strength of conclusions able to be drawn.

3.6 Conclusion and Implications

Consistent with current evidence, repositioning manoeuvres were effective in BPPV management if the primary outcome was resolution of signs and symptoms on positional tests. Despite successful repositioning manoeuvres, some participants experienced poor outcomes such as residual dizziness and balance impairment, recurrences, and psycho-emotional consequences, that in some cases persisted at 12 months. This review highlights the need to include serial assessment of balance and

mental health, as well as, patient education, falls measures and specific treatment to target domains identified as outside of normal limits on assessment. Additionally, older adults experienced less improvements, post repositioning manoeuvres, in dynamic standing balance and self-perceived level of handicap when compared with younger adults. These findings underscore the need to focus on, not just treating BPPV and improving the symptoms, but also on improving physical function and addressing the handicap effects caused by BPPV symptoms. Older adults with BPPV should also be monitored for falls. Future studies with better methodological quality are needed to further investigate and address the above-discussed problems in younger and older adults with BPPV.

Clinical Messages

- ❑ Despite successful repositioning manoeuvres, a moderate proportion of patients experienced incomplete recovery of some impairment outcomes.
- ❑ There is a need for serial assessment of BPPV signs and symptoms, gait, balance, and mental health outcomes for BPPV patients, and prescription of specific treatment for domains identified as outside normal limits
- ❑ Older age may be associated with poorer dynamic balance recovery and increased self-perceived level of handicap. Future studies should further investigate and address these issues.

Additional note: Systematic review findings in the context of this thesis

In general, the results from this systematic review emphasise the need for more older adults-focused studies, longer follow-up period, and the importance to explore other physical/functional and subjective outcomes in the management of older adults with BPPV. The subsequent studies in this thesis included measures from different domains including gait, balance (static/dynamic), vestibular, symptom severity, falls efficacy, falls, physical activity level, and mental health screening. The follow-up period for the longitudinal study was six months. The personal experiences of older adults were also explored to provide better insights into the problems they faced (as reflected in the quantitative self-report measures).

Chapter 4 Methods

4.1 Introduction

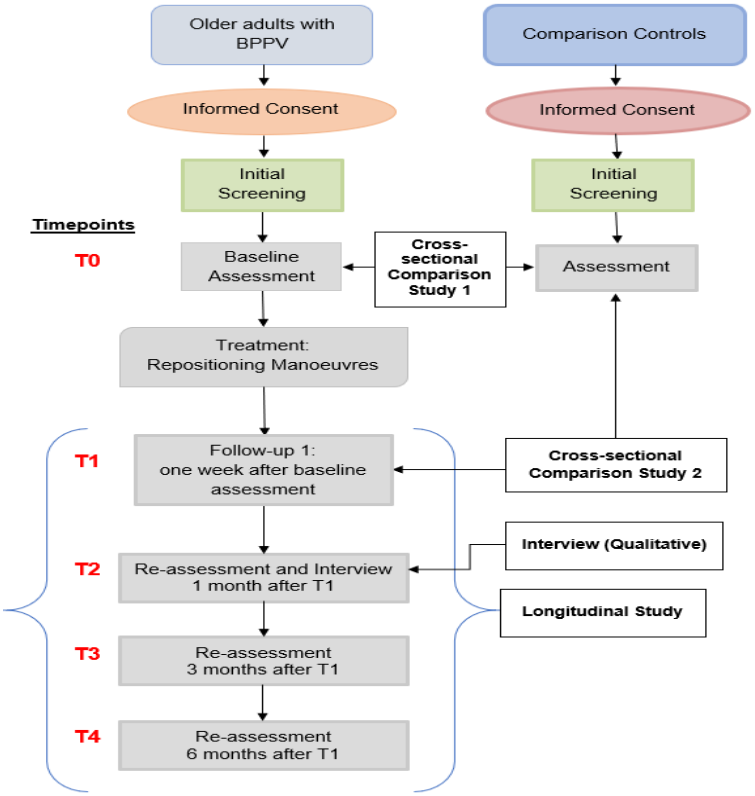
Chapter 3 presented a systematic review and meta-analysis of the available literature comparing treatment outcomes between older and younger adults with BPPV. This chapter introduces the quantitative and qualitative studies and describes the methods used in this research programme. The study design, sampling, recruitment details, data collection schedule and procedures, sample size calculation, data analysis, and data storage are detailed in this chapter. Ethical considerations are also discussed.

4.2 Research Design

The aims, of this PhD research, were to better understand residual dizziness in older adults with BPPV, and to gain comprehensive insights into their perceptions and treatment outcomes. The research programme comprised two cross-sectional quantitative components, a longitudinal quantitative component, and a qualitative component. Figure 4.1 shows the study flow diagram.

Cross-sectional studies 1 and 2 were designed to investigate if the BPPV group was comparable to the comparison control group in the performance of gait, balance, vestibular function, and self-report measures at study entry (T0) and about one week after undergoing initial repositioning manoeuvres (T1), respectively. Cross-sectional study 2 also included an exploration of factors associated with residual dizziness in older adults with BPPV. The longitudinal study involved six months of follow-up with four assessment time points (T1 – T4). The longer-term study was designed for monitoring of BPPV recurrences and changes in BPPV status; an exploration of factors associated with residual dizziness at six months; an exploration of physical performance and self-report measures associated with residual dizziness at six months; and for an exploratory investigation comparing falls between the BPPV and comparison control groups. The qualitative study, designed to explore the lived experiences of older adults with BPPV, was conducted at time point T2, which was about one month after the first follow-up. More information will be presented in the respective study chapters (Chapters 5, 6, and 7).

Figure 4.1 Study flow diagram



4.3 Participants

There were two groups of participants recruited for this research project: the BPPV group and the comparison control group. The BPPV group comprised of older adults with BPPV aged 55 years and above. The comparison control participants were older adults in the similar age range as the BPPV-group participants but did not have a history of vestibular problems or BPPV. The inclusion of the comparison control group was to provide a “normative” representation of older adults without BPPV. This allowed for comparisons to be made between the two groups in the domains of physical performance, vestibular function, self-report measures, and falls. Age- and gender-matching were initially planned. However, recruitment difficulties rendered it hard for proper matching to take place. Control for these confounders was performed through statistical adjustment.

4.3.1 Inclusion criteria

Participants must meet all the following criteria to be included in the studies:

BPPV group

1. Age 55 years and above.
   The initial lowest age limit was set at 60 years old (initial protocol). This was later amended to 55 years old, when recruitment rate was low, in an attempt to expand the pool of eligible patients and improve the recruitment numbers. The lowest limit of 55 years old was chosen because at this age, one qualifies for certain senior citizen discounts in Singapore (country where study took place).
2. Newly diagnosed or new onset of BPPV of the canalithiasis types (posterior/horizontal/anterior), confirmed by a positive positional test: Either untreated or had undergone not more than 2 sessions of treatment over the past one month for the existing episode of BPPV.
   Participants who were previously treated (≤ 2 sessions) were included because some patients would have had already undergone at least one treatment at the doctor's clinic before their physiotherapy appointment. This criterion was added after an evaluation of poor recruitment during the initial months. In the bid to improve the sample size by adding this criterion, the initial aim of investigating the prevalence of residual dizziness in older adults with BPPV could not be fulfilled as the participants would not all have the same starting point (not treated at all). Hence, that was removed from the objectives. Another potential impact of adding this criterion would be that these patients might perform better in the baseline (T0) physical performance and subjective outcomes (while still testing positive of BPPV) compared to those who had no prior treatment.
3. Be independent in activities of daily living and community ambulation. If an assistive device was needed, it was limited to the use of a single point stick for outdoor ambulation.
4. Ability to give informed consent. Demonstrated normal cognition with the ability to follow complex commands and in understanding the information (medical- and research-related) provided.

Comparison control group

1. Age 55 years old and above.
2. No history of any diagnosed vestibular problems.
3. Be independent in activities of daily living and be community ambulant. If an assistive device was needed, it was limited to the use of a single point stick for outdoor ambulation.
4. Ability to understand the study requirements and to give informed consent. Demonstrated normal cognition with the ability to follow complex commands and in understanding the information (medical- and research-related) provided.

4.3.2 Exclusion criteria

Participants were excluded if they met any of the following exclusion criteria:

Both BPPV and comparison control groups

1. History of neurological conditions affecting balance and mobility.
2. History of central vestibular lesions.
3. Presence of any painful or debilitating musculoskeletal conditions that might affect balance/mobility/testing; those with neck problems could be recruited but would not undergo the Video Head Impulse Test.
4. Inability to give informed consent or to follow complex instructions.
5. Needed supervision/assistance for activities of daily living or mobility.

BPPV group

1. BPPV post traumatic head injury.
2. Subjective BPPV (positive for history and positional testing but no nystagmus elicited).

4.3.3 Recruitment details

Recruitment took place in Singapore General Hospital (SGH), a tertiary hospital in Singapore, from June 2017 to February 2019. Participants with BPPV were recruited

from the Ear, Nose and Throat (ENT) and Physiotherapy clinics at SGH. All doctors and physiotherapists attending to patients with vestibular disorders were briefed on the study recruitment criteria.

At the ENT clinic, the on-site study team member (PhD student) screened through patient lists and medical notes to first identify possible eligible patients based on age, provisional diagnosis, and past medical history, as per inclusion/exclusion criteria. If BPPV canalithiasis was diagnosed on positional testing, and the doctor deemed the patient suitable to participate in the study, the study team member would discuss the study details with the patient and seek to obtain informed consent.

For recruitment at the Physiotherapy Outpatient Clinic, the on-site study team member (PhD student) screened through patient lists and relevant available medical information to identify potential patients. If the physiotherapist confirmed BPPV canalithiasis on positional testing and assessed the patient to be suitable to participate in the study, the physiotherapist then informed the patient about the study. Following that, the study team member spoke further to the patient about the study and proceeded to obtain informed consent.

Assessment findings from the study were provided to the physiotherapists looking after the participants to provide more clinical information for management planning. Written reports, containing pertinent findings and information, were provided to the doctors for subsequent medical appointments. Participants received their usual care in the treatment of BPPV (including repositioning manoeuvres and vestibular rehabilitation, medication, advice) through their treating staff at the source clinics. The study assessments were additional to these. For the participants with BPPV, if they continued to test positive or tested positive again for BPPV, they would undergo treatment as per usual clinical care.

For the comparison control group, participants were volunteers who might be spouses/relatives of SGH patients, SGH visitors/staff and/or other social contacts. Initial screens as per inclusion/exclusion criteria were conducted face to face or over a telephone call. If the volunteer passed the initial screen, an appointment for informed consent taking and assessment were made. At the appointment which took place at the Physiotherapy Outpatient Clinic at SGH, the volunteers underwent the positional tests to

confirm they did not have BPPV. If the volunteer fulfilled the recruitment criteria, informed consent was obtained, and the volunteer was recruited into the study. In the event there was an incidental finding of BPPV, the volunteer was ineligible for the study and was advised to see a doctor.

4.4 Assessments

4.4.1 Overview

Data collection took place from August 2017 to September 2019. Comparison control group participants were measured on one occasion (T0) but followed up for falls data over six months via phone calls (see section 4.4.9). Participants with BPPV were assessed on five occasions (see Figure 4.1):

- T0: Initial assessment; at study entry (both groups)
- T1: First follow-up assessment; one week after T0 (BPPV group)
- T2: Second follow-up; one month after T1 (BPPV group)
- T3: Third follow-up; three months after T1 (BPPV group)
- T4: Fourth and last follow-up assessment; six months after T1 (BPPV group)

The first follow-up (T1) took place about one week (seven ± three days) after study entry (T0). Following up one week after initial repositioning manoeuvres is a common clinical practice at the SGH Physiotherapy Vestibular Clinic. This timeline was also used in some studies investigating the efficacy of repositioning manoeuvres (Amor-Dorado et al., 2012; Cetin et al., 2018; Froehling et al., 2000; Yimtae et al., 2003). Previous studies had found that 50% of BPPV recurrence happened within the first six months (Hyo Jung Kim & Kim, 2017; Pérez et al., 2012). The duration of the longitudinal study was six months to enable longer-term monitoring and review of changes in the BPPV status. As data collection took place in a clinical setting, participants often preferred to arrange the study visit on the same day as their physiotherapy or medical appointment. Hence, some flexibility in the study timeline was needed and was built into the protocol to allow for small variations in the follow-up time.

When the study first started, the assessment protocol consisted of the positional tests, the Visual Analogue Scale (dizziness, vertigo and unsteadiness), the Vestibular Rehabilitation Benefits Questionnaire, the Activities-specific Balance Confidence Scale,

the Geriatric Anxiety Inventory, the Geriatric Depression Scale – 15, the Human Activity Profile, the Video Head Impulse Test, the Sensory Organisation Test using Neurocom's® Balance Master, the Dynamic Gait Index, and gait speed (comfortable and maximum/fast) using the GaitRite® gait analysis system. Assessments were conducted at the Physiotherapy Outpatient Clinic as the Neurocom® Balance Master and the GaitRite® electronic mat were located there. Table 4.1 reports all assessment measures, and the timing of their application for both groups of participants, and each test is described in detail below.

4.4.1.1 Changes to assessment procedures

Recruitment rate for BPPV participants was low six months into the study period. Factors that appeared to be contributing to low recruitment, apart from difficulty recruiting untreated patients, were the number of sessions required (five visits for BPPV group) and a general disinterest in research and research-related activities. Patients who were identified as potential subjects had also refused to participate in the study due to the time required (two to three hours per session). The participants recruited from the ENT Clinic also had to make their way to the Physiotherapy Clinic at another building for the initial assessment. The additional need to commute from one place to another for the assessment further reduced the willingness of potential subjects to participate in the study.

To improve recruitment rate, a decision was made to modify the protocol to make the assessment portable (for conducting assessment at the ENT clinic) and to shorten the time of assessment. Hence, after reviewing the assessment items in relation to the objectives of the study, a decision was made to remove the Sensory Organisation Test, the Dynamic Gait Index, comfortable gait speed and the use of the GaitRite®. In place, the Modified Clinical Test of Sensory Integration on Balance and the comfortable

Table 4.1 Assessment procedures (original protocol) and timeline for both BPPV and comparison control groups

	BPPV group					Comparison control group				
	T0	T1	T2	T3	T4	T0	T1	T2	T3	T4
Positional tests	√	√	√	√	√	√				
Walking speed (comfortable and maximum/fast)	√	√	√	√	√	√				
Sensory Organisation Test	√	√	√	√	√	√				
Video Head Impulse Test	√	√	√	√	√	√				
Dynamic Gait Index	√	√	√	√	√	√				
VAS (dizziness, vertigo, and unsteadiness)	√	√	√	√	√	√				
Vestibular Rehabilitation Benefits Questionnaire	√	√	√	√	√	√				
ABC	√	√	√	√	√	√				
Geriatric Anxiety Inventory	√	√	√	√	√	√				
GDS-15	√	√	√	√	√	√				
Human Activity Profile	√	√	√	√	√	√				
Number of falls	√	√	√	√	√	√	√	√	√	√

Note. VAS = Visual Analogue Scale; ABC = Activities-specific Balance Confidence Scale; GDS-15 = 15-item Geriatric Depression Scale.

walking speed with horizontal head movements were added (see Table 4.2). The same set of assessment items were conducted for all time points. Subjects who were recruited prior to the protocol change were assessed throughout using the former protocol for consistency and reliability.

The primary outcome measures for this series of studies were the Visual Analogue Scale (dizziness, vertigo, and unsteadiness), the Vestibular Rehabilitation Benefits Questionnaire (VRBQ), and walking speed (Fast gait speed and Comfortable walking speed with horizontal head turns). The secondary outcomes were the Activities-specific Balance Confidence Scale, the Geriatric Anxiety Inventory, the Geriatric Depression Scale – 15, the Human Activity Profile, the Video Head Impulse Test, the Modified Clinical Test of Sensory Integration on Balance, and the number of falls.

Table 4.2 Original and amended assessment protocol

Assessment Protocol	Original	Amended
Procedures	• Positional tests • Walking speed (*comfortable* and maximum/fast) +/- use of GaitRite® • *Sensory Organisation Test* • Video Head Impulse Test • *Dynamic Gait Index* • VAS (dizziness, vertigo, and unsteadiness) • Vestibular Rehabilitation Benefits Questionnaire • Activities-specific Balance Confidence Scale • Geriatric Anxiety Inventory • 15-item Geriatric Depression Scale (GDS-15) • Human Activity Profile • Number of falls	• Positional tests • Walking speed (maximum/fast and *comfortable with horizontal head turns*) without use of GaitRite® • *Modified Clinical Test of Sensory Integration on Balance* • Video Head Impulse Test • VAS (dizziness, vertigo, and unsteadiness) • Vestibular Rehabilitation Benefits Questionnaire • Activities-specific Balance Confidence Scale • Geriatric Anxiety Inventory • 15-item Geriatric Depression Scale (GDS-15) • Human Activity Profile

Assessment Protocol	Original	Amended
		• Number of falls
Participants	First 15 participants with BPPV and first four comparison control participants	Remaining 25 participants with BPPV and 16 comparison control participants

Note. Italicised procedures under the original protocol were the ones removed in the amended protocol; and the italicised procedures in the amended protocol were the ones added; VAS = Visual Analogue Scale.

4.4.2 Vestibular Rehabilitation Benefits Questionnaire (VRBQ)

The Vestibular Rehabilitation Benefits Questionnaire (VRBQ) (Morris, Lutman, & Yardley, 2009) is a 22-item self-report questionnaire used to assess the efficacy of vestibular rehabilitation on patients' symptoms and impact on their quality of life (see Figure 4.2). This patient reported outcome has two parts: Part A on symptoms (dizziness, anxiety, and motion-provoked dizziness), and Part B on how the symptoms affect the individual's quality of life. It makes a comparison between the patient's current state and his/her normal state.

The responses were made on a seven-point scale and scores were awarded according to a pre-set scoring template (see Appendix D). For the symptom subscales, relevant individual scores are added to form the subscale raw score. The raw score was then multiplied by a pre-determined value in the respective % deficit box to form the final score (% deficit). The symptom and quality-of-life summary scores were calculated in a similar way while the total summary score was obtained by adding together both symptom and quality-of-life raw scores and multiplying by the pre-determined value. The scores may range from zero to 100%, with zero indicating no deficits and 100% indicating a markedly impaired state (Morris et al., 2009).

The internal consistency of the subscores, as measured by Cronbach's alpha, were 0.73 (VRBQ Total), 0.89 (VRBQ Dizziness), 0.74 (VRBQ Anxiety), 0.91 (VRBQ Motion-provoked Dizziness) and 0.92 (VRBQ Quality of Life) (Morris et al., 2009). Test-retest reliability has also been shown to be excellent with the following intraclass coefficients: 0.92 (VRBQ Total), 0.99 (VRBQ Dizziness), 0.99 (VRBQ Anxiety), 0.98 (VRBQ Motion-provoked Dizziness), and 0.94 (VRBQ Quality of Life) (all p values < 0.001) (Morris et al., 2009). The VRBQ also correlated with the Dizziness Handicap Inventory (Pearson's r = 0.44), the Vestibular Symptoms Scale-

short form (Pearson's *r* = 0.45) and the Medical Outcomes Study Short Form 36 (SF 36) (Pearson's *r* = -0.27 to -0.33) in subjects undergoing vestibular rehabilitation (Morris et al., 2009).

There was no validated Chinese version as at the start of the study. However, as the vestibular physiotherapists in the Singapore General Hospital were conducting their own validation study (incomplete as of current date) as well as using the Chinese translation in the clinical setting, this study used the afore-mentioned Chinese version of VRBQ (see Figure 4.2 with both English and Chinese versions in one). A Certificate of Translation was submitted for review and was granted approval by the SingHealth CIRB. However, participants who were only able to read the VRBQ Chinese version were still guided through the questionnaire verbally by the researcher, even with the translation in-situ.

Figure 4.2 Vestibular Rehabilitation Benefits Questionnaire (VRBQ)

The following questionnaire asks your **dizziness** on a **typical day** in the **last week** - please do not include problems that you think are caused by another conditions. Please answer **all** of the questions by circling **one** of the answer options.
请您把在过去一星期内具有代表性的一天的头晕程度填写在下。请不要将头晕以外的其它因素考虑在内。请回答所有问题，并圈出一个最符合您情况的选项。

Part A – your symptoms 您的症状 This section is about how often you experience different feelings. 这部分是关于您多经常经历以下的感受。							Scores (official use)
1. I feel dizzy **我感到头晕**							
all of the time	very often	quite often	Sometimes	not very often	only very occasionally	never	
每时每刻	非常经常	蛮常	有时候	不是很经常	很少有	从来没有	D
2. I get a feeling of tingling, prickling or numbness in my body **我感觉到身体刺痛或麻痹**							
all of the time	very often	quite often	Sometimes	not very often	only very occasionally	never	
每时每刻	非常经常	蛮常	有时候	不是很经常	很少有	从来没有	A
3. I have a feeling that things are spinning or moving around **我感觉到周围的东西在旋转或移动**							
all of the time	very often	quite often	Sometimes	not very often	only very occasionally	never	
每时每刻	非常经常	蛮常	有时候	不是很经常	很少有	从来没有	D

4. I feel as though my heart is pounding or fluttering **我感觉到心跳加重或加快**							
all of the time	very often	quite often	Sometimes	not very often	only very occasionally	never	
每时每刻	非常经常	蛮常	有时候	不是很经常	很少有	从来没有	A
5. I feel unsteady, as though I may lose my balance **我感觉到不稳，好像有可能会失去平衡**							
all of the time	very often	quite often	Sometimes	not very often	only very occasionally	never	
每时每刻	非常经常	蛮常	有时候	不是很经常	很少有	从来没有	D
6. I have difficulty breathing or feel short of breath **我感觉到呼吸困难或喘不过气**							
all of the time	very often	quite often	Sometimes	not very often	only very occasionally	never	
每时每刻	非常经常	蛮常	有时候	不是很经常	很少有	从来没有	A
This section is about how dizzy you get when you move around. 这个部分是关于您移动时头晕的程度。 Please do not circle 'not at all dizzy' if you avoid making the movement – either try the movement or talk to your balance therapist before answering. 如果您为了避免头晕而不做某些动作，请勿在此项目圈“完全不晕”-请您先试一试那个动作或与您的治疗师交谈后再作答。							
7. Bending over makes me feel **向前弯腰使我感到**							
not at all dizzy	very slightly dizzy	mildly dizzy	moderately dizzy	really quite dizzy	very dizzy	extremely dizzy	
完全不晕	极少晕	稍微晕	中等晕	真的蛮晕	非常晕	极度的晕	M
8. Lying down and / or turning over in bed makes me feel **躺下或在床上翻身时，我感到**							
not at all dizzy	very slightly dizzy	mildly dizzy	moderately dizzy	really quite dizzy	very dizzy	extremely dizzy	
完全不晕	极少晕	稍微晕	中等晕	真的蛮晕	非常晕	极度的晕	M
9. Looking up at the sky makes me feel **抬头望天使我感到**							
not at all dizzy	very slightly dizzy	mildly dizzy	moderately dizzy	really quite dizzy	very dizzy	extremely dizzy	
完全不晕	极少晕	稍微晕	中等晕	真的蛮晕	非常晕	极度的晕	M
10. Moving my head <u>slowly</u> from side to side makes me feel **慢慢地左右转头使我感到**							

not at all dizzy	very slightly dizzy	mildly dizzy	moderately dizzy	really quite dizzy	very dizzy	extremely dizzy	M
完全不晕	极少晕	稍微晕	中等晕	真的蛮晕	非常晕	极度的晕	
11. Moving my head <u>quickly</u> from side to side makes me feel **快速地左右转头使我感到**							
not at all dizzy	very slightly dizzy	mildly dizzy	moderately dizzy	really quite dizzy	very dizzy	extremely dizzy	
完全不晕	极少晕	稍微晕	中等晕	真的蛮晕	非常晕	极度的晕	M
Part B – how the dizziness is affecting you 头晕对您的影响 Please read each question carefully – some of the statements are phrased to suggest that you have difficulty (for example, 'I have trouble focusing my eyes') and some are phrased to suggest you <u>do not</u> have difficulty (for example, 'I feel comfortable travelling'). If a question does not apply to you, please circle 'same as before' rather that leaving it out. 请仔细回答以下问题，有些是指您在做某些动作时有困难（例如："我有困难集中目光"），有些是指您在做某些动作时没有困难（例如："我可以轻松地外出"）。请回答所有问题。任何不适用的问题，就请选择"和以前一样"，请勿留空。							Scores (official use)
12. Compared to before the dizziness, I feel comfortable travelling **和在未有头晕之前相比，我能自如地旅行**							
a lot more	quite a bit more	a little bit more	same as before	a little bit less	quite a bit less	a lot less	
多很多	多蛮多	稍微多些	和以前一样	稍微少些	比较少	少很多	Q
13. Compared to before the dizziness, I feel confident **和在未有头晕之前相比，我感到自信**							
a lot more	quite a bit more	a little bit more	same as before	a little bit less	quite a bit less	a lot less	
多很多	多蛮多	稍微多些	和以前一样	稍微少些	比较少	少很多	Q
14. Compared to before the dizziness, I have difficulty looking after myself (for example, washing my hair, cleaning my teeth, dressing myself, etc) **和在未有头晕之前相比，我在照顾自己方面有困难** **例如：自己洗头、自己刷牙、自己穿衣服等）**							14. reverse scoring
a lot more	quite a bit more	a little bit more	same as before	a little bit less	quite a bit less	a lot less	
多很多	多蛮多	稍微多些	和以前一样	稍微少些	比较少	少很多	Q
15. Compared to before the dizziness, I feel comfortable going out alone **和在未有头晕之前相比，我能自如地独自外出**							
a lot more	quite a bit more	a little bit more	same as before	a little bit less	quite a bit less	a lot less	
多很多	多蛮多	稍微多些	和以前一样	稍微少些	比较少	少很多	Q

16. Compared to before the dizziness, I can concentrate and / or remember things **和在未有头晕之前相比，我可以集中注意力和/或记住事情** a lot more / 多很多	quite a bit more / 多蛮多	a little bit more / 稍微多些	same as before / 和以前一样	a little bit less / 稍微少些	quite a bit less / 比较少	a lot less / 少很多	Q
17. Compared to before the dizziness, I need to hold on to something for support **和在未有头晕之前相比，我需要抓住东西支撑自己** a lot more / 多很多	quite a bit more / 多蛮多	a little bit more / 稍微多些	same as before / 和以前一样	a little bit less / 稍微少些	quite a bit less / 比较少	a lot less / 少很多	17. reverse scoring Q
18. Compared to before the dizziness, I think my quality of life is good **和在未有头晕之前相比，我觉得我的生活素质不错** a lot more / 多很多	quite a bit more / 多蛮多	a little bit more / 稍微多些	same as before / 和以前一样	a little bit less / 稍微少些	quite a bit less / 比较少	a lot less / 少很多	Q
19. Compared to before the dizziness, I avoid some activities, positions or situations **和在未有头晕之前相比，我会避免某些活动，姿势或情形** a lot more / 多很多	quite a bit more / 多蛮多	a little bit more / 稍微多些	same as before / 和以前一样	a little bit less / 稍微少些	quite a bit less / 比较少	a lot less / 少很多	19. reverse scoring Q
20. Compared to before the dizziness, I am happy to be on my own **和在未有头晕之前相比，我独自一人也开心** a lot more / 多很多	quite a bit more / 多蛮多	a little bit more / 稍微多些	same as before / 和以前一样	a little bit less / 稍微少些	quite a bit less / 比较少	a lot less / 少很多	Q
21. Compared to before the dizziness, I feel stable in the dark or when my eyes are closed **和在未有头晕之前相比，我在黑暗里或闭着双眼时都能保持平稳** a lot more / 多很多	quite a bit more / 多蛮多	a little bit more / 稍微多些	same as before / 和以前一样	a little bit less / 稍微少些	quite a bit less / 比较少	a lot less / 少很多	Q
22. Compared to before the dizziness, I take part in social activities **和在未有头晕之前相比，我参与社交活动** a lot more / 多很多	quite a bit more / 多蛮多	a little bit more / 稍微多些	same as before / 和以前一样	a little bit less / 稍微少些	quite a bit less / 比较少	a lot less / 少很多	Q

Note. The VRBQ (original version in English) is available at http://resource.isvr.soton.ac.uk/audiology/vrbq.htm. The Chinese translation was part of an ongoing validation study at that point in time and was also used in the clinical setting where the study was being conducted. There was no validated Chinese version available at the start of the study.

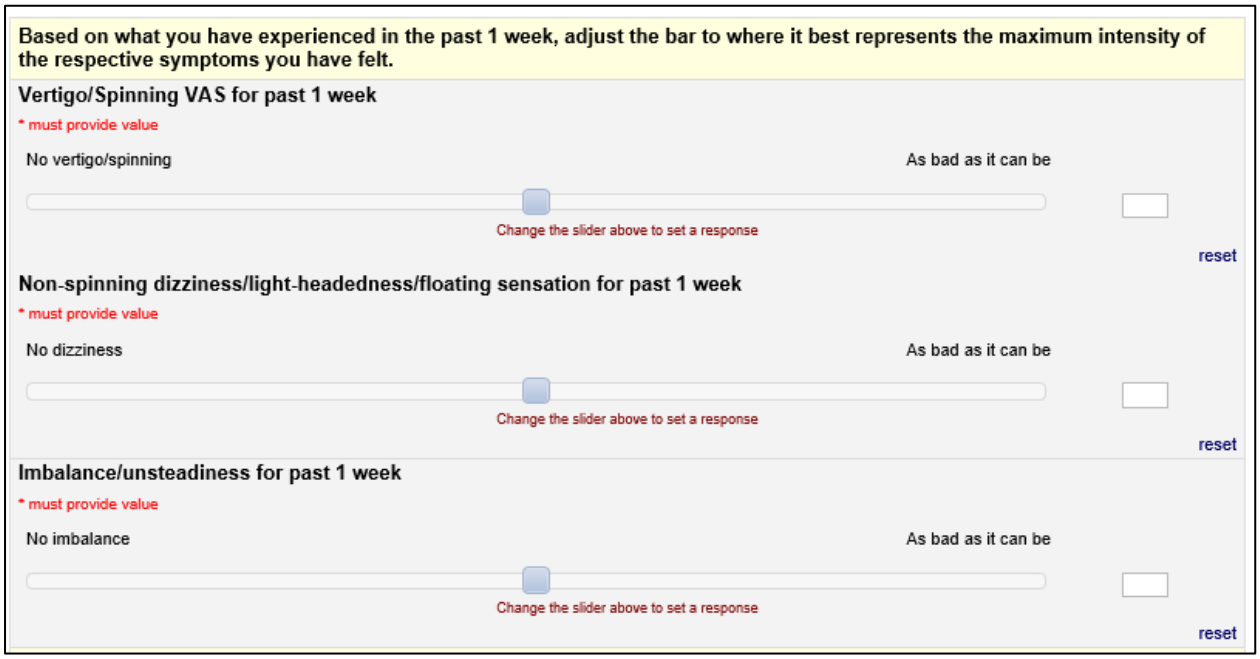
4.4.3 Visual Analogue Scale (VAS) for intensity of vertigo, dizziness, and unsteadiness

The VAS (McCormack, Horne, & Sheather, 1988) is a global rating scale often used to quantify subjective experiences such as pain, fatigue, dyspnoea, and mood. It is easily administered, with responders indicating a point along a 10cm line that best represents how they feel. The 10cm line represents a 100-point scale (measured out in mm) ranging from 0 (total absence of the targeted experience) to 100 (worst intensity of the experience) (McCormack et al., 1988). The VAS was found to be one of the most used patient-reported outcomes in clinical vestibular research (Fong, Li, Aslakson, & Agrawal, 2015). In the BPPV population, the VAS had been used to measure various symptoms: vertigo (Michel Toupet, Ferrary, & Bozorg Grayeli, 2012; M. Toupet, Ferrary, & Grayeli, 2011), dizziness (Augusto Pietro Casani et al., 2019; Michel Toupet et al., 2012; M. Toupet et al., 2011), and nausea/vomiting (Augusto Pietro Casani et al., 2019). It was also used to rate the global quality of life (Uz, Uz, Akdal, & Celik, 2019).

The VAS was used in this thesis to measure the intensity of three different symptoms experienced by participants over the week prior to the assessment: vertigo, dizziness, and unsteadiness (see Figure 4.3). Dizziness, vertigo, and unsteadiness were defined according to the International Classification of Vestibular Disorders I (ICVD-I) developed by the Committee for the Classification of Vestibular Disorders of the Bárány Society (A. Bisdorff et al., 2009). Dizziness was defined as "the sensation of disturbed or impaired spatial orientation without a false or distorted sense of motion" and is non-vertiginous in nature (A. Bisdorff et al., 2009, p. 7). Vertigo was "the sensation of self-motion when no self-motion is occurring or the sensation of distorted self-motion during an otherwise normal head movement" (A. Bisdorff et al., 2009, p. 5). It also included false sensations such as spinning, swaying, tilting, bobbing, bouncing, or sliding (non-spinning vertigo) (A. Bisdorff et al., 2009). Unsteadiness was defined as "the feeling of being unstable while seated, standing, or walking without a particular directional preference" (A. Bisdorff et al., 2009, p. 9) and should decrease or be eliminated by added support such as holding onto a stable wall (A. Bisdorff et al., 2009). The VAS in this study was administered over the SingHealth Research Electronic Data Capture (Redcap) database (online) using a scrollable scale, with one end representing no symptom (score of 0) and the

other end representing “as bad as it can be” (score of 100) (see Figure 4.3). The participants were instructed to indicate their responses by placing the cursor (where appropriate) along the scale for all three symptoms. For participants who were non-English speaking, the scale was verbally translated either by the assessor or interpreter (usually person accompanying the participant i.e., family member).

Figure 4.3 The Visual Analogue Scale for dizziness, vertigo and unsteadiness set up for this study (as accessed on the SingHealth Redcap database)



4.4.4 Walking speed (m/s)

Walking speed tests have been well established to be an inexpensive, yet valid and reliable method in providing useful information that can be used as indicator of health status and functional capacity (Fritz & Lusardi, 2009). In a recent study on gait speed tests in female older adults, both normal and fast gait speeds were found to have good test-retest reliability when conducted over four-metre, six-metre, and 10-metre walkways (H. J. Kim, Park, Lee, & Lee, 2016). Another study investigated the effect of walkway length (five-, eight- and 10-metre) on the walking speed of older adults. The authors reported that walkway length did not affect the comfortable and maximum walking speed of older adults (Ng et al., 2013).

The initial protocol for this study consisted of both comfortable and maximum walking speeds (Middleton, Fritz, & Lusardi, 2015). With the change in protocol, the

comfortable walking speed was removed and replaced with the comfortable walking speed with horizontal head turns (A. Shumway-Cook, Taylor, Matsuda, Studer, & Whetten, 2013)(a test item in the Dynamic Gait Index). The maximum or fast walking speed was retained in the new protocol. The change was made to shorten the assessment duration but keep it robust. Faster gait speed (comfortable, maximum/fast, or comfortable with horizontal head turns) indicated better performance.

4.4.4.1 Comfortable walking speed (removed)

Participants were instructed to walk at their normal comfortable speed (Bohannon, 1997) and informed that it was a timed test. The GaitRite® portable gait analysis system was used for the initial 15 participants. The GaitRite® electronic mat is 7-metre long and 0.89-metre wide, and connects to a computer for operation, providing users comprehensive temporo-spatial gait parameters (see Figure 4.4). The active area of the electronic mat is 6-metre long and 0.61-metre wide. The GaitRite® portable gait analysis system has been proven to be valid and reliable for use in the gait assessment of adults with vestibular problems (Schmidheiny et al., 2015). The walk began two metres before and ended two metres after the mat to allow for acceleration and deceleration. No shoes were worn when the walking test was conducted on the GaitRite® mat. None of the participants required the use of walking stick for the test. The walk was also timed with a stopwatch (as a backup). The timing (using the stopwatch) started when the leading foot crossed the start of the mat and stopped when the leading foot crossed the end of the mat. In the event when the GaitRite® system was not available, this test was performed using the conventional overground 10-metre (10m) test using the stopwatch, over a total 14-metre walkway (two metres before and after for acceleration and deceleration). For walking tests not conducted on the GaitRite® electronic mat, participants walked barefooted if the footwear was not appropriate such as heels and slippers. Measures were taken to ensure the floor was clean and safe, and foot hygiene was observed after every walk. Each walking test (conducted on GaitRite® or overground) was carried out twice and the results averaged to give the final value.

Figure 4.4 The GaitRite® electronic mat

4.4.4.2 Maximum or fast walking speed

Participants were instructed to “walk as fast and as safely but without running” (Bohannon, 1997). As with comfortable walking speed, the test was conducted either using the GaitRite® or a 14-metre walkway depending on availability of GaitRite®. The test was carried out twice and the results were averaged to give a final value for gait speed (m/s).

With the change in assessment protocol, the test was conducted over a 10-metre walkway. The timed walk was over a six-metre walkway, with two metres before and after to allow for acceleration and deceleration (Middleton et al., 2015).

4.4.4.3 Comfortable walking speed with horizontal head turns

This item of walking with horizontal head turns was selected from the Dynamic Gait Index test (DGI) (Anne Shumway-Cook & Woollacott, 1995). The reason for choosing this item was based on studies that have found people with balance/vestibular disorders exhibiting significant dysfunction with this test (Dye,

Eakman, & Bolton, 2013; G. F. Marchetti, Whitney, Blatt, Morris, & Vance, 2008). However, the DGI item test scores were not used. The data collected was the time taken for the walk (seconds). The walking speed measure for walking with horizontal head turns (as an individual DGI item) for subjects with vestibular or balance disorders demonstrated excellent test-retest reliability (Intraclass Correlation Coefficient 0.97, CI [0.93, 0.99]) (G. F. Marchetti et al., 2008). In this study, this test was timed over a six-metre walkway instead of the 6.1m (20 feet) walkway set out in the DGI instructions. Six metres is also the active length of the GaitRite® electronic mat. This distance was chosen to maintain comparable results for all participants

The participant was instructed before the start of the test: to start walking at a normal pace and try to keep to a straight path; when the assessor said, “Look right”, keep walking straight but turn the head to the right; keep looking right until the assessor said, “Look left”, keep walking but turn head to left; Keep looking left until the assessor said, “Look straight”, keep walking straight and return head to centre. The assessor began timing, using a stopwatch, when “begin/start” was being announced and stopped timing when the first foot of the participant crossed the six-metre mark. The walk was repeated twice with the average time taken over the two walks used to calculate the gait speed (m/s). The comparable data for this test, for the first 15 participants with BPPV and the first four control participants, were extracted from GaitRite® gait analysis software whenever available. The test was stopped if the participant lost balance or veered excessively. The participant was reminded to keep to the path while performing the walk. The test was repeated to complete collection of two viable tests. Faster gait speed in this test indicated better performance.

4.4.5 Positional tests

There are three positional tests: The Dix-Hallpike test (DHP), the side-lying test and the roll test. The DHP test (Dix & Hallpike, 1952) is a test manoeuvre for identifying BPPV in the posterior and anterior canals. To perform this test, the participant started in the long sitting position with their head rotated 45 degrees to the side being tested. The examiner gently but firmly held the participant’s head in this alignment and in a single motion, brought the participant into the supine position with the head extended and over the edge of the bed. This position was maintained for up to a minute while the examiner monitored the participant for the characteristic

nystagmus and subjective complaint of vertigo. If necessary, modifications were made to the manoeuvre to ensure comfort and safety of the participant. One modification of the Dix-Hallpike test is by performing it with a pillow under the shoulders. This modification eliminates the need for head-hanging and for the examiner to support the participant's head. It was found to have good efficacy and beneficial for patients who are anxious or unsuitable for the head-hanging position (Jeon et al., 2019). The side-lying test, also known as the Semont Diagnostic Manoeuvre, is an alternative test to the DHP test (Halker, Barrs, Wellik, Wingerchuk, & Demaerschalk, 2008). For this test, the participant sat over the edge of the bed with the head turned 45 degrees away from the side being tested. The participant was then quickly brought onto the bed on the side being tested and the examiner observed the participant's eyes for nystagmus. For both DHP and the side-lying tests, an upbeating and torsional nystagmus, with a latency on onset and lasting less than one minute, indicated the presence of posterior canalithiasis. The torsional component is usually towards the dependent ear (tested ear) indicating the affected side. On the other hand, a downbeating torsional nystagmus most likely indicates anterior canalithiasis.

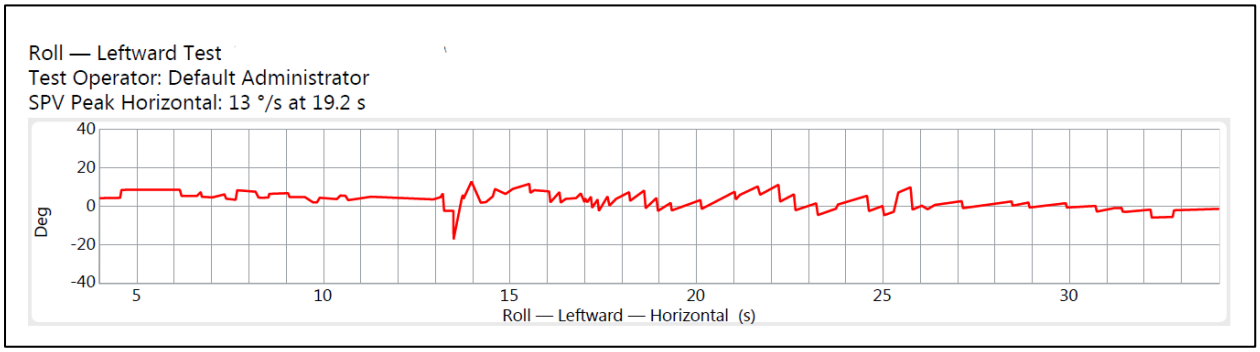
The Roll test (Pagnini-Lempert or Pagnini-McClure Roll Test) (Lempert & Tiel-Wilck, 1996; McClure, 1985) is used to assess for BPPV in the horizontal canals. For this test, the participant started lying supine with the neck flexed to 30 degrees and supported by the examiner. The head was then quickly rolled 90 degrees to one side and held there for up to one minute while observing for nystagmus and its direction. The head was turned slowly back to the midline before the same procedure was repeated for the other side. Horizontal canalithiasis is typically characterised by vertigo and geotropic (towards gravity) nystagmus, present on testing either side. The affected side is the side with the stronger symptoms (more intense vertigo and nystagmus).

The positional tests were performed, and the spontaneous eye movements were recorded using the ICS Impulse System (GN Otometrics). The ICS Impulse System allows for the assessment of the vestibulo-ocular reflex (VOR) and nystagmus by recording, measuring, and analysing eye and head movements (see Figure 4.5). The positional test results were collected in two ways: as per clinical practice – positive or negative (categorical), and as quantified by the peak slow phase velocity (SPV, °/s) of the nystagmus (continuous) (see Figure 4.6). As

torsional nystagmus is a hallmark of BPPV of the vertical canals, the peak SPV of the torsional direction was collected for both posterior canalithiasis and anterior canalithiasis. For horizontal canalithiasis, the peak SPV of the horizontal direction of the nystagmus was recorded.

Figure 4.5 The ICS Impulse (GN Otometrics) goggles and software

Figure 4.6 Slow phase velocity captured during left roll test



4.4.6 Video Head Impulse Test (vHIT)

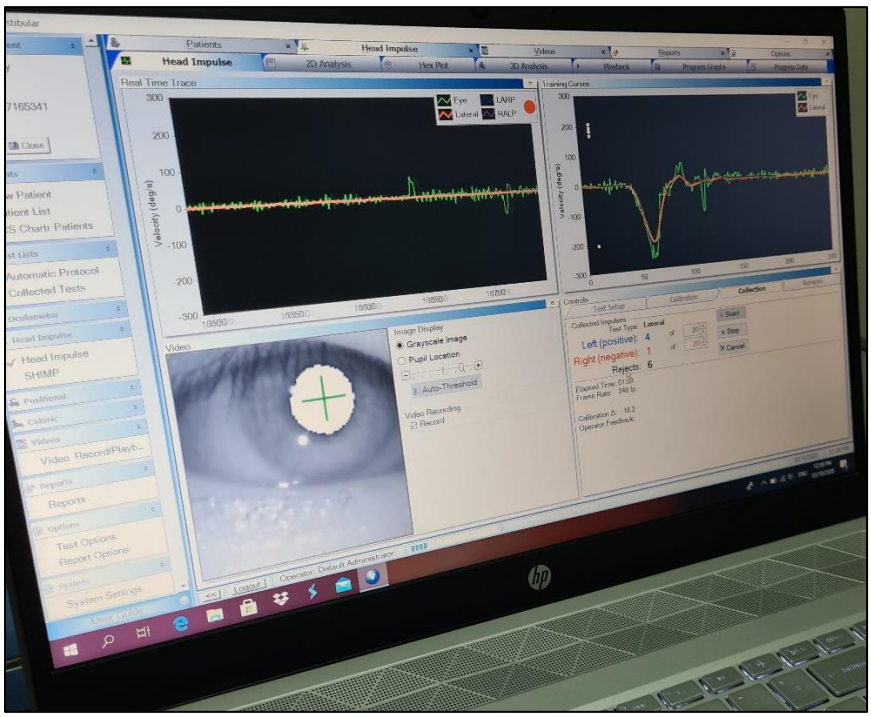
The vHIT (MacDougall et al., 2009) was used to assess the integrity of the three pairs of semicircular canals. The vHIT combines the use of a high speed digital video camera with the bedside test, the Head Impulse Test (HIT) (Halmagyi & Curthoys, 1988) to assess the semi-circular canals, quantified by the amount of gaze deviations during passive head movements termed as “Gain”. Traditionally, the HIT could only assess the horizontal canals. The vHIT system allows for examination of the anterior and posterior canals, as well as capturing of covert gaze deviations, which may otherwise be easily missed.

The vHIT was validated against the gold standard for measuring eye movements during HIT, the scleral search coil technique (MacDougall et al., 2009). The test-retest reliability was excellent (Pearson’s r = 0.99) for both vHIT and the scleral search coil technique. The concordance correlation coefficients (rc) between both tests for head movement and eye movement recordings were 0.999 and 0.930, respectively. In measuring gaze deficit, the vHIT and the scleral search coil technique did not differ significantly as well for both patient group (mean difference = 0.040, n = 8, t = 1.930, p = .073) and control group (mean difference = 0.043, n = 8, t = 1.717, p = .107). The vHIT device used in this thesis was the ICS Impulse (GN Otometrics) System (see Figure 4.7).

The vHIT assesses the semicircular canals in three planes: horizontal (right and left), right anterior-left posterior (RALP) and left anterior-right posterior (LARP). The participant wore the vHIT goggles and sat facing a coloured sticker (fixation dot) on a wall, at least one metre away. For the horizontal plane, the participant was instructed to focus visually on the coloured sticker while the assessor performed unpredictable head thrusts to the left and right from behind. For RALP, the participant turned his/her head 35 to 45 degrees to the left. This position ensured that when the assessor performed the head thrusts in the pitch movement, the right anterior and left posterior semicircular canals were the only canals stimulated. The same principle applied for LARP, with the participant’s head turned 35 to 45 degrees to the right while the assessor performed unpredictable thrusts up and down. The results generated were the gains for all six semicircular canals. As recommended by GN Otometrics and based on a study by MacDougall et al (MacDougall et al., 2009), the normal range for horizontal gain is from 0.8 to 1.2 while that for the vertical gain (anterior and posterior) is from 0.7 to 1.2 (GN Otometrics, 2016). These set ranges

are congruent with the age-based normative horizontal and vertical gains found in healthy individuals aged between 10 to 89 years old (McGarvie et al., 2015).

Figure 4.7 Horizontal vHIT with right head impulse test tracing shown on the screen



4.4.7 Modified Clinical Test of Sensory Integration on Balance (mCTSIB)

The CTSIB (Cohen, Blatchly, & Gombash, 1993; A. Shumway-Cook & Horak, 1986) is a clinical balance assessment derived from the Sensory Organisation Test (SOT) (Peterka & Black, 1990). It was modified further with the removal of the use of the visual conflict dome. The mCTSIB assesses the amount of time (up to 30 seconds) one can maintain balance under four different conditions: Eyes open and closed while standing on a stable surface, and eyes open and closed while standing on a foam surface. The mCTSIB may be conducted without instrumentation in clinical settings (Peterka & Black, 1990) or using the Smart Balance Master (Neurocom® International, Inc) (which provides Centre of Pressure measures). In this study, the mCTSIB was performed using the floor, a foam pad, and a stopwatch (no instrumentation).

Participants were tested on each of the four testing conditions in the order described above. Each test was conducted with the participants standing with their

feet together (barefooted) and arms crossed over the chest, and for a total duration of 30 seconds. Instructions to participants for the eyes open tests were “With your eyes open and looking ahead, stand as steady as you can for 30 seconds and please do not talk”. Instructions for the eyes closed stable surface tests were “Keep your eyes closed, stand as steady as you can for 30 seconds and please do not talk”. Instructions were modified regarding keeping the eyes open or eyes closed, and the support surface (floor or foam pad) depending on the test condition. Tests were stopped under the following conditions: (i) when the participants opened their eyes during eyes closed trials; (ii) uncrossed arms; (iii) lost balance or required help from falling; or (iv) moved the feet from the starting position. For safety, the participants stood next to a raised plinth with a sturdy chair in front for support (when needed). The assessor stood next to the participants on the other side to ensure patient safety while conducting the assessment.

4.4.8 Activities-specific Balance Confidence Scale (ABC)

The ABC (Powell & Myers, 1995) is a self-reported outcome that evaluates confidence in maintaining balance while performing mobility related activities. It is a 16-item questionnaire with each item rated on a scale of zero to 100, zero being no confidence at all in performing the activity without overbalancing and 100 indicating full confidence (see Appendix E). It has been validated for use in samples with vestibular disorders and has moderate to strong correlations with the Dizziness Handicap Inventory (r = -0.64) (Whitney, Hudak, & Marchetti, 1999), the Dynamic Gait Index (r = 0.58) (Legters, Whitney, Porter, & Buczek, 2005) and Timed-Up and Go (r = -0.4) (Gregory F. Marchetti, Whitney, Redfern, & Furman, 2011). The validated Chinese version of ABC (Guan et al., 2012) was used together with the original English version.

4.4.9 Number of falls

Participants from both BPPV and comparison control groups were interviewed at the baseline assessment (Cross-sectional Study 1) on their fall history for the previous six months. For this study, a fall was defined as “an unexpected event in which the participant comes to rest on the ground, floor, or lower level’’ (Lamb, Jørstad-Stein, Hauer, & Becker, 2005, p. 1619). Data on the location, nature, cause, and related injuries of the falls were collected. Subsequent falls were monitored

prospectively from Cross-sectional Study 1 (T0) through to the last follow-up assessment (Longitudinal study, T4). Fall data were collected monthly prospectively for Study 3 (Ganz, Higashi, & Rubenstein, 2005). Fall diary and phone call follow-ups were used for monitoring falls. The Fall diary were for the participants to record the fall events should any occur. For the comparison control participants, the diaries were not intended to be collected back as they would not be returning for further sessions. The participants in the BPPV group were informed that the diaries were to be collected back on the last follow-up session (T4). The monthly phone calls were to follow up on any falls for all the participants (both BPPV and comparison control groups). Another purpose of the phone calls was to check on the participants in the BPPV group if they did not have any scheduled sessions for that month.

4.4.10 Human Activity Profile (HAP)

The HAP (Daughton, Fix, Kass, Bell, & Patil, 1982) is a self-report outcome that measures level of physical activity in the form of energy expenditure (see Appendix F). It comprises 94 activities, ranging from low energy expenditure ones like getting in and out of bed or chair, to high energy expenditure ones like playing basketball or soccer. Participants were instructed to rate each activity using one of three responses: “still doing this activity”, “have stopped doing this activity” or “never did this activity”. The estimated maximum activity (EMA; also known as maximum activity score, MAS) and the adjusted activity score (AAS) were calculated to determine the level of physical activity of the participant. The MAS was the number of the activity with the highest metabolic cost that the participant still performed. The AAS was calculated by adding the total number of lower-numbered activities below the MAS that the participant had stopped doing and subtracting that number from the MAS. The AAS ranges from zero to 94, with a higher score indicating increased physical activity level (Bilek, Venema, Willett, & Lyden, 2008). It is a reliable and valid measure of physical activity across several conditions, and its responsiveness, as estimated by the trend of effect sizes, were appropriate for the interventions given (Davidson & de Morton, 2007). The Chinese translated version of HAP by Bonner et al (2006) was used in conjunction with the English version.

4.4.11 Geriatric Depression Scale-15 (GDS-15)

The GDS-15 (see Appendix G) is a shortened version of the original 30-item GDS, designed for detecting depression in the older population, and is well correlated with the original version ($r=0.84$, $p<0.001$) (Yesavage & Sheikh, 1986). In a large validation study with 4253 Asian older adults, the GDS-15 was shown to have good internal consistency (Cronbach alpha of 0.8), good test-retest reliability (ICC 0.83), high positive predictive value (0.42), and excellent sensitivity (0.97) and specificity (0.95) (AUC 0.98) in detecting major depression at a cut-off score of 4/5 (Nyunt, Fones, Niti, & Ng, 2009). Differences in age, gender, ethnic, and health-status did not affect test performance (Nyunt et al., 2009). The response format is Yes/No and can be answered by the patient in two to three minutes. A systematic review on screening tools for depression in older adults in the community concluded it is suitable for use in the clinic or the community (Watson & Pignone, 2003).

The Australian Chinese version of the GDS-15 is used along with the English version for the participants who could only read Chinese. It is available online (website: https://web.stanford.edu/~yesavage/GDS.html). The Australian Chinese version (Dow et al., 2018) was derived following minor changes (terms used to describe emotions) made to its predecessor – the standard GDS-15 (GDS-S) (Mui, 1996). The GDS-S was found to be reliable and valid in the screening for depression in Chinese older immigrants living in Australia (Dow et al., 2018).

4.4.12 Geriatric Anxiety Inventory (GAI)

The GAI is a valid and reliable self-reporting measure for detecting anxiety in older adults (Pachana et al., 2007). It consists of 20 questions with responses in the agree/disagree format (see Appendix H). The maximum score is 20, with higher scores signifying higher anxiety. In a study with both clinical and control samples (Johnco, Knight, Tadic, & Wuthrich, 2015), the GAI was shown to have good internal consistency (Cronbach's alpha of 0.854 (clinical sample) and 0.714 (control)). A cut-off score of 8/9 has been recommended for the detection of anxiety in older adults with a sensitivity of 69.5% and specificity of 100%. A review by Therrien and Hunsley (2012) found it to be a suitable tool for screening of anxiety in the older population.

An application for the non-commercial use license for GAI was made (via the UniQuest eShop [website: *https://eshop.uniquest.com.au/*]) including the request for both the English and the Chinese-Singapore versions of the questionnaire. The non-

commercial use license for GAI was issued (see Appendix I for the email approval from the UniQuest eShop), along with the requested questionnaires (English and Chinese-Singapore versions) (see Appendix H).

4.4.13 Sensory Organisation Test (SOT) (replaced with mCTSIB, see section 4.4.7)

The SOT (Peterka & Black, 1990) comprises of six sensory test conditions, in which balance is to be maintained for 20 seconds per trial and there is a total of three trials per condition. The six conditions are:

- Eyes open on firm surface
- Eyes closed on firm surface
- Eyes open on firm surface and sway referenced visual surround
- Eyes open on sway referenced support surface
- Eyes closed on sway referenced support surface
- Eyes open on both sway referenced support surface and visual surround

The equilibrium score, based on the amount of postural sway measured by the force platform, is calculated for each trial of all six conditions. The equilibrium scores are used to calculate the composite score, indicating overall balance performance across the six conditions for the overall assessment. This test is also able to identify the impaired sensory modalities (visual, vestibular, or somatosensory) as they affect postural control. In healthy non-institutionalised older adults, the SOT composite score was found to have good reliability (test-retest, ICC 0.66) but poor (ICC 0.26 for Condition 3) to fair (ICC 0.64 and 0.68 for Conditions 5 and 6 respectively) reliability for SOT average of three trials (Ford-Smith, Wyman, Elswick, Fernandez, & Newton, 1995). In a large retrospective study of 2384 patients who underwent SOT and vestibular testing, the estimated sensitivity of SOT in identifying abnormal sensory patterns was 95% (Hamid, Hughes, & Kinney, 1991). The SOT was conducted on the Smart Balance Master by Neurocom® International, Inc.

4.4.14 Dynamic Gait Index (DGI) (removed)

The DGI (Anne Shumway-Cook & Woollacott, 1995) was developed to assess the ability to balance while walking under different physical demands such as changing speeds, turning head (horizontally and vertically), stepping over obstacles, turning, and stairs climbing (see Appendix J). The test contains eight items, each

graded on a four-point ordinal scale from zero (severe impairment) to three (no gait dysfunction). The total score ranges from zero to 24, with higher scores indicating less impairment. In adults with vestibular conditions, DGI was found to have good test-retest reliability (ICC 0.86 for total score; individual item ICC: 0.04 – 0.90) (C. D. Hall & Herdman, 2006), moderate inter-rater reliability (total score: Cohen's kappa = 0.64 and Spearman's Rho = 0.95) (Wrisley, Walker, Echternach, & Strasnick, 2003), and adequate concurrent validity with the Berg Balance Test (Spearman's Rho = 0.71) (Whitney, Wrisley, & Furman, 2003); hence, supporting its use for assessing balance and gait, as well as in identifying potential fallers in people with vestibular disorders.

4.5 Sample Size Calculation and Feasibility

The sample size estimation of this group of studies was based on the longitudinal study as it was the most complex. Based on the guideline of at least 15 participants per degree of freedom (df), the required sample size was 180 (df 12). Considering 20% attrition rate, the sample size required was 216. For the longitudinal study, based on Generalised Least Squares, the Effective Sample Size formula (Faes, Molenberghs, Aerts, Verbeke, & Kenward, 2009) (see Figure 4.8) with four follow-up time points and a correlation of 0.5 between measures (within each participant) was used. The effective sample size is defined as "the sample size one would need in an independent sample to equal the amount of information in the actual correlated sample" (Faes et al., 2009, p. 389). Based on the formula, a target sample size of 108 participants in the BPPV group with four follow-up assessments would yield an equivalent amount of data as 216 individual participants; and could support up to 14 predictors, assuming linear predictor effects. Hence, the target number of participants in the BPPV group was 108. The target sample size for the comparison control group was also 108 based on a 1:1 ratio. Based on the estimation of number of 35 eligible BPPV participants per month and recruitment rate of 30%, it was anticipated prior to the study that it would take about 11 months to recruit 108 participants for the BPPV group. Consecutive sampling method was utilised.

As discussed earlier, the actual recruitment did not materialise as projected. Recruitment for the BPPV group was poor. Eligible patients were not always keen to join the study because of time (each session was about two hours or more with

interspersed rests) and the number of follow-up sessions. Some patients did not mind answering surveys at that point in time but were not keen for further engagement. In trying to improve recruitment numbers, multiple protocol revisions were made to shorten assessment duration, improve assessment portability, and modify subject selection criteria while maintaining study aims/objectives and protocol robustness. The recruitment of comparison control participants, partly affected by the initial focus on recruitment of participants with BPPV, also fell below expectation. From June 2017 to February 2019 (entire recruitment period), the total numbers of participants in the BPPV and comparison control groups recruited were 40 and 20, respectively.

Figure 4.8 The Effective Sample Size Formula

$$\tilde{N} = \frac{n - (n-2)\rho}{1+\rho} N.$$

Note. $\tilde{N}$ = Effective sample size; n = number of follow ups; ρ = Correlation between measures; N = actual correlated sample size. Formula as published in "The Effective Sample Size and an Alternative Small-Sample Degrees-of-Freedom Method", by Faes et al, 2009, *The American Statistician*, 63(4), p. 392.

4.6 Qualitative Study

Qualitative research methods allow for the exploration of concepts, phenomena, and experiences of the target group. As discussed in Chapter 2 (Literature Review), there is a paucity of literature on the lived experiences of patients with BPPV. This study was undertaken with the aim of exploring the experiences of older adults with BPPV: how BPPV and its management impact on the psychosocial and physical aspects of their lives. The qualitative method used was the semi-structured in-depth interviews, which were conducted one-to-one using a combination of closed- and open-ended guiding questions. This interview method provides opportunities for the conversation to go into unpredicted areas while centering around a main agenda (Adams, 2015). All participants in the BPPV group were invited to participate in this qualitative study. The participants indicated their consent or non-consent to the interviews in the Participant Information and Consent Form (PICF). It was also indicated in the PICF that the interviews would be recorded for the purpose of data collection.

The interviews were conducted at the second follow-up (T2; about five weeks from study entry) by the PhD candidate (see Figure 4.1). This time point was chosen for various reasons. First, it was hoped that most participants, by this time point, would be BPPV-free and in a better state to undergo the interview. Second, being five weeks into the study, the participants would have undergone at least a couple or more treatment sessions and the experiences would still be fresh in their minds. Third, setting a time point further away might run the risks of attrition and losing the opportunity to capture the data. A consultation room in the SGH Physiotherapy Clinic was used for the interviews to ensure privacy and comfort for the interviewees. The audio-recorder was placed in full sight of the interviewees and no patient identifiers were used during the interview. The interviews were conducted mainly in English. Mandarin or a mixture of English and Mandarin were used for some participants.

In qualitative studies, sampling is usually terminated at the point of saturation. Data saturation is attained when analysis yields no new information and new data can be considered redundant (Moser & Korstjens, 2018). The recruitment for the interviews was planned to the point of data saturation in this study.

With no prior experience with qualitative research, the researcher (PhD candidate) enrolled in a 2-week qualitative research course (The IPSA-NUS Summer School for Social Science Research Methods – Qualitative Data Analysis and Interviews and Focus Group Research). The study team also sought help from the SGH Health Services Research Unit. It assigned a research associate (EL) with qualitative research experience to help and provide guidance to the researcher. The initial interview schedule (list of guiding questions) was drafted when the researcher was attending the qualitative research course. She shared the list of guiding questions with the course instructor who provided some feedback. The interview schedule was not pilot-tested. Further discussions and revisions of the interview schedule were made through consultations with EL and the supervisors, and informal consultations with fellow vestibular physiotherapists. Prior to the first interview, the researcher had practice runs with EL to familiarise herself with the process. EL also sat in with the researcher during the first four interviews: to observe, provide help if needed, and to provide feedback to the researcher.

4.7 Data Analysis

4.7.1 Quantitative studies

For descriptive statistics, the mean and standard deviation, and 25th, 50th, and 75th percentiles are presented. Parametric tests were used to analyse baseline demographic data which were normally distributed. If not, non-parametric tests were used. The overall statistical method used for analyses in this research programme was the regression analysis. Regression analysis uses models to estimate the relationship between one dependent variable and one or more independent variables. It is often used for forecasting and prediction. However, Harrell (2015) argued that the model-based approach is also effective and appropriate for hypothesis testing and effect estimation. The quantitative studies in this research programme were observational in nature. Unlike RCTs, observational studies are prone to confounding (Meuli & Dick, 2018). The use of multivariable regression analysis is one way of controlling for confounding (Kahlert, Gribsholt, Gammelager, Dekkers, & Luta, 2017).

In the cross-sectional studies, multivariable linear regression was used to estimate the differences in the results between participants with BPPV and comparison controls for physical performance and self-report measures. The physical measures included walking speeds (maximum/fast and comfortable walking with horizontal head turns), balance (mCTSIB), and vestibular function (left/right horizontal VOR gains). The self-report measures were the VRBQ (Total/Anxiety/QOL scores), VAS (vertigo/dizziness/unsteadiness), ABC, HAP (MAS/AAS), GAI, and GDS-15.

At first follow-up (T1), one week after initial repositioning manoeuvres, the analyses were between participants who remained positive (T1 BPPV-positive) and comparison controls, and between participants who tested negative for BPPV (T1 BPPV-negative) and comparison controls. At T1, analysis was also done to explore which factors might be associated with residual dizziness in older adults. As previously mentioned, residual dizziness can be experienced as non-vertiginous dizziness and/or unsteadiness, despite testing negative on positional tests and without positional vertigo. Hence, separate models were used, with T1 VAS dizziness- or unsteadiness- score as dependent variable, respectively. The factors (independent variables) investigated were age, gender, duration of BPPV symptoms (onset to treatment), baseline (T0) and follow-up (T1) VRBQ Anxiety subscale,

baseline (T0) and follow-up (T1) GAI, baseline (T0) and follow-up (T1) GDS-15, and the number of comorbidities (baseline).

For the longitudinal study, the changes in BPPV status (positive, negative, or negative with residual dizziness) and recurrence were descriptively presented. Recurrence was defined as “a change in BPPV status, confirmed by positional test(s), from a prior “negative” (with or without residual dizziness) to “positive” as at the time of testing.”

The negative binomial regression was used to analyse the difference in the number of falls between the BPPV and comparison control groups. This would be exploratory as the study was not powered to detect the difference in the number of falls between the two groups. Negative binomial regression model is suitable for comparing recurrent event rates between groups, and with an over-dispersed count variable such as falls (Robertson, Campbell, & Herbison, 2005).

In the six months following the initial repositioning manoeuvres, assessments were conducted at the four follow-up time points for each participant. One caveat with the longitudinal data is that the data collected for each participant over time would be more similar than those across different participants. Disregarding this correlation between repeated measurements can result in inaccurate results including invalid *p* values (Ntoumanis, 2014; Schober & Vetter, 2018). The linear mixed effects model or multilevel modelling accounts for this correlation by allowing a random intercept and/or random slope, hence the starting points and changes over time may vary across the subjects (Ntoumanis, 2014; Schober & Vetter, 2018).

The linear mixed effects model was used to explore the factors associated with residual dizziness in older adults with BPPV at six months. As with the cross-sectional studies, the VAS dizziness and unsteadiness scores were assigned as dependent variables in separate models. The factors (independent variables) investigated included age, gender, number of comorbidities (baseline), duration of BPPV symptoms, history of BPPV, living arrangement, VRBQ Anxiety subscale, GAI, and GDS-15.

The relationships between residual dizziness, and the physical performance and self-report measures were also investigated using multilevel modelling. The dependent variables were the walking speeds (maximum/fast and comfortable walking with horizontal head turns), balance (mCTSIB), VRBQ (Total/Anxiety/QOL), GAI, GDS-15, ABC, and HAP. Each dependent variable was included in two

separate models with either VAS dizziness- or unsteadiness- score as a factor (independent variable).

As discussed earlier, the regression analyses provided for the adjustment or control of confounding variables and covariates. It is important to minimise the risk of confounding. Adjustment for covariates and confounders were made in the regression analyses performed for all cross-sectional and longitudinal studies mentioned earlier. The covariates in the models included age, gender, number of comorbidities (baseline), and baseline values (VAS dizziness/unsteadiness scores and number of falls). Age and gender matching were not possible at recruitment and had to be adjusted for. Concurrently, age could be a confounding variable given its associations with certain dependent variables (i.e., walking speed and dizziness) and independent variables (i.e., dizziness, unsteadiness, and history of BPPV). A higher number of comorbidities could be associated with dizziness (Lindell, Kollén, Johansson, Karlsson, Rydén, Zettergren, et al., 2020).

The actual number of follow-up -days (cross-sectional study 2) and -weeks (longitudinal study) differed between subjects, these were also controlled for in the relevant models. For BPPV status, the convention is to use the clinical dichotomous description of positive and negative. However, it is more advantageous to use a continuous variable in the analysis as opposed to using a categorical equivalent of the measure (Altman & Royston, 2006). Hence, the peak slow-phase velocity (°/s) of the positional nystagmus captured during the representative positional test was chosen as a proxy for BPPV status.

4.7.2 Qualitative study

The data analysis approach used is the thematic analysis (Braun & Clarke, 2006). Thematic analysis is described as “a method for identifying, analysing and reporting patterns (themes) within data” (Braun & Clarke, 2006, p. 79). Themes are patterns or meanings within the data that are important to the research question (Braun & Clarke, 2006). The thematic data analysis in this qualitative study followed the six-phase process outlined by Braun and Clarke (2006): Familiarising with the data; generation of initial codes; searching for themes; reviewing themes; defining and naming the themes; and lastly, generating the report.

Familiarising one with the data involves transcribing the data, reading the transcripts repeatedly, and taking note of initial ideas (Braun & Clarke, 2006). The

recorded interviews were transcribed verbatim and proof-read by another team member to ensure accuracy of transcription. Discrepancies or mistakes in the transcripts were highlighted, discussed, and corrected. After the first phase of familiarising with the data, two researchers (EL and ES – PhD candidate) formally worked on generating codes from the data sets independently. This also included organising the data extracts or quotes from the interviews under the relevant codes. Following that, both researchers worked on identifying the main- and sub-themes including reorganising the codes and data extracts as necessary. The researchers first reviewed the themes independently. Following that, they reviewed, refined, and named the themes together. Any disagreements on the codes, themes, and data extraction were resolved through discussions between the researchers and in consultation with the main supervisor (KH). The results were also discussed and finalised with the main supervisor (KH). As the data set was small (n = 13), data management was done using Microsoft Excel.

4.8 Ethical Considerations

The studies in this thesis have been approved by both the SingHealth Centralised Institutional Review Board (Singapore) and Curtin University Human Research Ethics Committee (see Appendices K and L).

4.8.1 Informed consent

For the BPPV group, potential participants were identified at the outpatient clinics during their consultations with the doctors or physiotherapists for their dizziness/vertigo problem. Once identified, the doctor or physiotherapist spoke to the eligible participant about the study. Thereafter the PhD student (on-site study team member) went through the study information in detail with the eligible participant and obtained informed consent. Potential participants were given adequate time to consider about the study within the time frame of their consultation with the doctor or physiotherapist for their BPPV condition, including waiting time for procedures. This time frame was chosen as the study team did not wish to delay the treatment for the patients beyond their consultation with the doctors or physiotherapists. Potential participants were also given time until their next physiotherapy appointment (if within one month) if they wished for a longer time before consenting. They were then recruited if they remained positive for BPPV and consented to participating in the

study. In addition, potential participants had the option of contacting the study team member if they decided to participate in the study before their next physiotherapy appointments. Emphasis on voluntary participation in the study were made during recruitment. The eligible patients were also reassured that refusal to participate in the study or withdrawal from the study at any point in time would not affect their care in the hospital.

For the comparison control group, there was an initial screening, either via phone call or face to face, followed by confirmation of eligibility at first appointment via positional tests to screen for BPPV. Pertinent study details were conveyed at that point. Potential participants would have time between the phone call screens to the actual appointment date to consider. They were also given time on the first appointment to consider after the study details were fully conveyed to them. Emphasis on voluntary participation in the study were made during recruitment. Reassurance was given to the eligible participants that they had the right to refuse to participate in the study or withdraw from the study at any point in time as they deemed appropriate.

All informed consents were taken with and documented in the Research Participant Information Sheet and Consent Form (PICF) (see Appendix M; latest version). For non-English speaking participants, the information and consent taking were delivered through a translator and documented in the PICF.

4.8.2 Participant safety and rights

The safety of participants was of utmost priority and took precedence over study procedures. Vital signs (blood pressure, heart rate, and when required, oxygen saturation) were taken at the start and monitored during each session. The participants with BPPV faced increased falls risk as well as discomfort associated with vertigo and nausea/vomiting. If there was any abnormality (i.e., high blood pressure) or if the participant felt unwell, activities would be stopped immediately, and the participant rested. The session would be terminated if the problem persisted. The participant would be allowed to go home only when assessed to be well.

Procedures such as the positional tests, the Sensory Organisation Test, and the Video Head Impulse Test may trigger vertigo/dizziness and great discomfort in the participants, especially those with BPPV. In addition, the duration of the entire session was long (approximately two hours or more) and could be tiring for older

adults. Participants were closely monitored and provided rests whenever needed. For participants who exhibited distress with positional vertigo, they could take their medication prior to the session if they found it helpful. Care and modifications to the assessment procedures were made to maximise comfort and reduce anxiety for the participants. But if he or she refused to undergo the assessment despite the modifications offered, the decision would be respected.

4.8.3 Confidentiality of data and patient records

All participants were given a participant code and all data gathered were de-identified. Confidential details of the participants were kept in a master list file and locked up in the research cupboard in the Physiotherapy Department at the Singapore General Hospital. Data collection forms (hardcopies) were also kept locked up but in a different cupboard, away from the master list file. Only relevant personnel associated with the study had access to these files. Soft copies of the de-identified data collected were stored on the SingHealth RedCap (online database) and in the encrypted Research hard drive. All folders and documents were password protected. Audio recordings and transcripts of the interviews only contained information such as date, time, and participant code to help identify the file if required at a later date. Soft copies of the recordings were stored in the encrypted, password protected hard drive, which was also stored in the research cupboard under lock and key. Only study team members had access to the soft copies with the prior knowledge of the Principal Investigator.

Chapter 5 Physical Performance and Mental Health of Older Adults with BPPV versus Comparison Controls Before and After Repositioning Manoeuvres (Cross-sectional Studies 1 and 2)

5.1 Abstract

Benign Paroxysmal Positional Vertigo (BPPV) is a common cause of peripheral vertigo and is more prevalent in older people. Although repositioning manoeuvres can be effective in resolving dizziness symptoms in most patients with BPPV, some may experience problems including residual dizziness and anxiety that could impact on function and quality of life. Two cross-sectional studies aimed to compare the results of physical performance and self-report measures between a group of 40 older adult subjects with BPPV and a group of 20 comparison control subjects, at baseline and seven days after initial repositioning manoeuvres, respectively. The cross-sectional study 2 also aimed to explore possible factors associated with residual dizziness post successful repositioning manoeuvres. Statistical analyses were conducted using the multivariable regression analysis. At baseline, participants with BPPV performed significantly worse than the comparison control subjects across all physical performance and self-report measures except the Geriatric Anxiety Inventory and Geriatric Depression Scale Short Form - 15 items. After initial repositioning manoeuvres, 18 subjects with BPPV achieved negative positional test results while 22 remained positive. Of those who achieved BPPV resolution, nine reported residual dizziness. Age, the number of comorbidities, and concurrent level of anxiety were found to be factors associated with residual dizziness post initial repositioning manoeuvres.

5.2 Introduction

The previous chapter detailed the methods used in this thesis: the study design, sampling, recruitment details, data collection schedule and procedures, sample size calculation, data analysis, and ethical considerations. The cross-sectional studies are discussed in this chapter.

Benign Paroxysmal Positional Vertigo (BPPV) affects people of all ages. However, adults aged 60 years old and above were found to be seven times more likely to have BPPV when compared with adults aged between 18 and 39 years old

(von Brevern et al., 2007). Older adults with BPPV might not complain of the classic symptom of vertigo. A small number of studies reported older adults (Batuecas-Caletrio et al., 2013; Piker & Jacobson, 2014; Plodpai et al., 2014) tended to describe unsteadiness or imbalance and non-specific dizziness as their main symptoms.

Older adults with BPPV exhibited poorer balance and gait when compared with healthy controls (Lena Kollén, Frändin, Möller, Olsén, & Möller, 2012). They were also found to experience more gait abnormalities and increased falls compared with younger counterparts or older adults with other types of dizziness (Lawson et al., 2008). Oghalai et al (2000) reported older adults with BPPV were 6.5 times more likely to fall compared to those without BPPV. The afore-mentioned cross-sectional studies involved older adults, recruited at an out-patient Falls Unit (Lawson et al., 2008) and a Geriatric out-patient Clinic (Oghalai et al., 2000), who were then screened for both falls history and BPPV. A recent paper (Jumani & Powell, 2017) also reported that a significant number of older adults with BPPV seen in their facility were primarily referred for falls and found to have BPPV on examination. Apart from problems with physical function, older adults with BPPV may also be affected psycho-emotionally. One study found them to have poorer mental health and decreased quality of life, as measured by the 36-Item Short Form Survey (SF36) and the Dizziness Handicap Inventory Short Form (DHI-S) (Gamiz & Lopez-Escamez, 2004).

Repositioning manoeuvres are the current gold standard treatment for BPPV. The Epley/Modified Epley Manoeuvres or Canalith Repositioning Manoeuvre have been reported to have an efficacy of >90% in just one to two treatment sessions (Reinink et al., 2014). The Semont Liberatory Manoeuvre has a similar efficacy rate (Hilton & Pinder, 2014; Zhang et al., 2017). Other repositioning manoeuvres include the Gufoni (Appiani/Casani) and the Barbeque roll for horizontal canal BPPV. Their reported efficacies ranged from 60% to 80% (Appiani et al., 2001; J. S. Kim et al., 2012). Apart from abating vertigo and achieving negative positional tests, some studies reported improvement in postural stability post BPPV treatment (Kasse et al., 2012; Vaz et al., 2013). Two retrospective studies also reported a reduction in the number of falls after repositioning manoeuvres (Gananca et al., 2010; Jumani & Powell, 2017). However, there remains a dearth of prospective BPPV-related falls data in older adults.

Based on the systematic review we performed as part of this PhD (Chapter 3), static balance improved significantly for both older (⩾60 years old) and younger adults (<60 years old) post BPPV resolution with repositioning manoeuvres. However, the change in dynamic balance and the Dizziness Handicap Inventory (DHI) score were significantly different between the two groups, with the older adults faring worse in terms of recovery. Blatt et al (2000) found that some older adults with BPPV did not achieve normal postural stability post repositioning manoeuvres while younger adults showed better improvement in this area. In addition, persistence of BPPV and residual dizziness post BPPV resolution have been reported by a small number of studies to be more prevalent in older adults (Babac et al., 2014; Batuecas-Caletrio et al., 2013; Teggi et al., 2011). Persistence of dizziness and unsteadiness in older adults may result in falls (A. Bisdorff, Bosser, Gueguen, & Perrin, 2013; Gazzola, Ganança, Aratani, Perracini, & Ganança, 2006); and could lead to serious consequences such as further restriction of activities, loss of confidence, decreased quality of life, social isolation, and functional/emotional decline (Choi, Jeon, & Cho, 2017; Gazzola et al., 2006; Iwasaki & Yamasoba, 2015; Payette et al., 2016). In contrast, other studies did not find an age effect on these problems (Abou-Elew et al., 2011; N. H. Lee et al., 2009). Some hypothesised factors associated with residual dizziness include persistent debris in the semi-circular canal, delayed vestibular adaptation after treatment, co-existing vestibular problems, duration of BPPV symptoms, anxiety, and utricular/otolithic dysfunction (Giommetti et al., 2017).

Given the above-mentioned conflicting evidence and the limited information on older adults with BPPV, this study aimed to investigate the impact of BPPV and initial repositioning manoeuvres on both physical performance and self-report measures, and to explore the factors associated with residual dizziness, in this population.

5.3 Objectives

1. To compare measures of vestibular function, balance and gait, balance confidence, falls risk, and mental health in older adults with BPPV, with comparison controls.

2. To explore the effectiveness of initial repositioning manoeuvres in older adults with BPPV.
3. To compare measures of vestibular function, balance and gait, balance confidence, falls risk, and mental health of both BPPV-positive and BPPV-negative groups **after initial repositioning manoeuvres**, with comparison controls.
4. To identify the factors associated with residual dizziness despite a negative Dix-Hallpike test, after initial repositioning manoeuvres in older adults with BPPV.

5.4 Methods

Two cross-sectional studies were undertaken between a sample presenting with BPPV, and a comparison control group: the first one was conducted before repositioning manoeuvres were administered to the BPPV group (T0), and the second was conducted one week after initial repositioning manoeuvres/study entry for this group (T1). T0 was also considered the study entry point for all participants, including the comparison control group (see Figure 5.1). Ethical approvals for the cross-sectional studies were obtained from the SingHealth Centralised Institutional Review Board (CIRB) (Singapore, CIRB reference 2016/2799) (see Appendix K) and the Curtin University Human Research Ethics Committee (HREC) (Australia, HREC reference HRE2017-0008) (see Appendix L).

The details of the methods used such as inclusion and exclusion criteria, recruitment, and outcome measures used have been reported in Chapter 4 (Methods). A summary is included here.

5.4.1 Participants

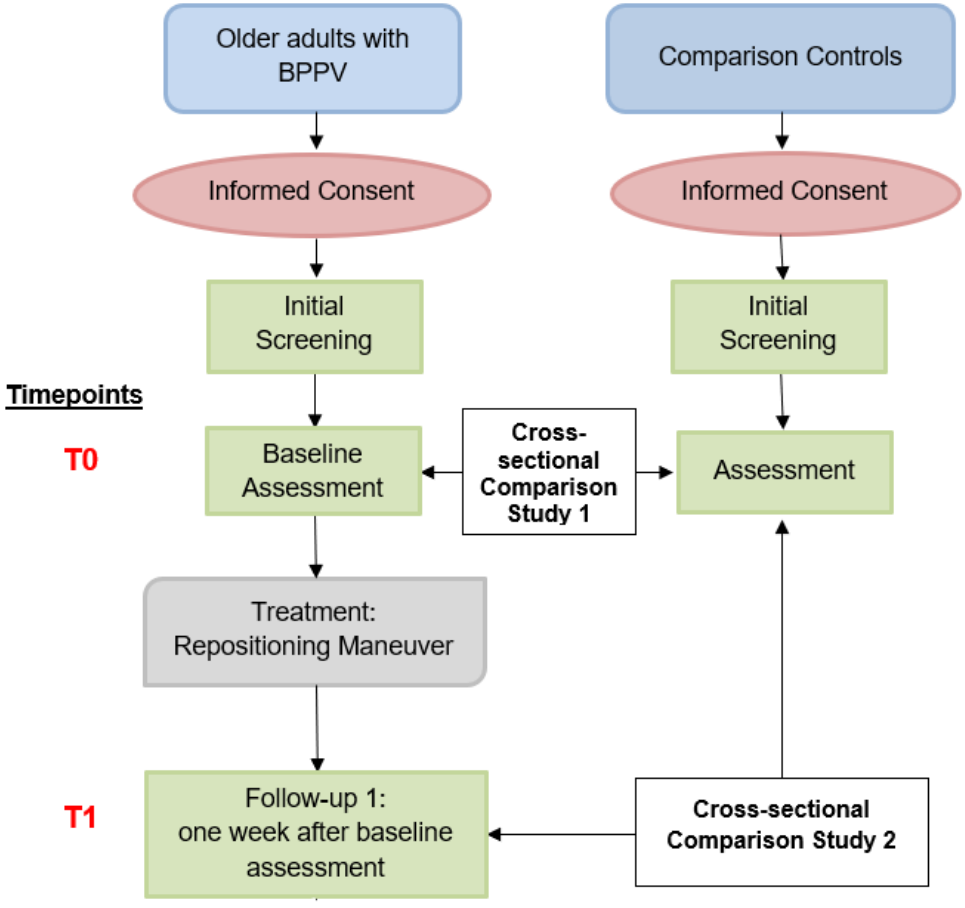
The participants comprised two different groups: the BPPV group and the comparison control group. The inclusion criteria for both groups were age of 55 years old and above, being functionally independent and community ambulant, using no gait aid or only a walking stick - for outdoor ambulation only (if a walking aid was required). A diagnosis of canalithiasis (either untreated or had ≤ 2 treatment in the preceding one month) was required for the BPPV group. Comparison control participants should not have any history of vestibular pathology. Potential participants were excluded if they had any neurological or musculoskeletal

conditions that affected balance and mobility, previous central vestibular lesion, or were unable to follow complex commands. More details on the participants are provided in Chapter 4 (section 4.3).

5.4.2 Procedure

As the settings were busy clinical areas in an acute hospital – the Physiotherapy Outpatient and the ENT Clinics, there were constraints of space sharing and availability. Hence, the sequence of the assessment items could not be fixed as flexibility was required to perform the assessments without hindering clinical services or prolonging the session. Moreover, as the assessment protocol comprised several physical tests and questionnaires which could potentially tire the older adults, flexibility in testing sequence was important to minimise fatigue.

Figure 5.1 Flowchart showing the study timepoints and components for Cross-sectional Studies 1 and 2



The BPPV group underwent two separate assessment sessions which were aimed to be seven (±three) days apart for the cross-sectional studies 1 (T0) and 2 (T1), respectively. The control comparison group was assessed only once (T0) but their results were used for comparison with the BPPV group at both time points. The assessment protocols were the same for both cross-sectional studies, except for the demographic and medical history data which were collected only at T0. Demographic data collected included gender, age, marital status, work status (i.e., retired, home-maker, working full/part time), highest education level, home situation (i.e., living alone, with family or friends), and premorbid mobility status.

The subjective component of the protocol consisted of the self-rating of intensity of symptoms (non-vertiginous dizziness, vertigo, and unsteadiness) and several self-report questionnaires to evaluate the impact of BPPV on the functional, disability, and psycho-emotional aspects of the older adults' lives. The questionnaires used were the Vestibular Rehabilitation Benefits Questionnaire (VRBQ) (Morris et al., 2009), the Activities-Specific Balance Confidence Scale (ABC) (Powell & Myers, 1995), the Human Activity Profile (HAP) (Daughton et al., 1982), the Geriatric Anxiety Inventory (GAI) (Pachana et al., 2007), and the 15-Item Geriatric Depression Scale (GDS-15) (Nyunt et al., 2009). These questionnaires were originally published in English. As the study was conducted in Singapore where Chinese is the majority race, the questionnaires (ABC, HAP, GAI, GDS-15, and VRBQ) needed to include Chinese translation to provide for the Chinese older adults who were unable to read English. These were presented in Chapter 4. There was one participant who could only understand Tamil, the questionnaires were completed with the help of a translator (a family member).

The physical assessment items included the positional tests, walking tests, balance assessment, and the Video Head Impulse Test (vHIT). These outcome measures were described in detail in the previous chapter (Chapter 4). The first 15 participants from the BPPV group and the first four participants from the comparison control group underwent the original protocol: comfortable and maximum/fast walking speed tests, Sensory Organisation Test (SOT), Dynamic Gait Index (DGI), vHIT, and positional tests (see Table 4.2, Chapter 4). Recruitment rate was low. Some potential participants attributed the reasons for rejecting participation to the lengthy assessment and the amount of time required. Hence some modifications were made to the assessment protocol, which came into effect for the subsequent 25

BPPV participants and 16 comparison control participants. Their assessment followed a revised assessment protocol which involved: walking speed tests (maximum/fast and comfortable walk with horizontal head turns), Modified Clinical Test of Sensory Integration on Balance (mCTSIB), vHIT, and positional tests (see Table 4.2, Chapter 4).

5.5 Statistical Analysis

For descriptive statistics, the mean and standard deviation; and 25th, 50th, and 75th percentiles are presented. For baseline demographic data, parametric tests were used to analyse those which were normally distributed. Otherwise, non-parametric tests were used.

Multivariable linear regression was used to examine the differences in the physical performance and self-report outcomes between the BPPV- and the comparison control- groups while adjusting for age, gender, and the number of comorbidities.

Separate multivariable linear regression models were used to evaluate the associations of (i) age; (ii) gender; (iii) number of comorbidities; (iv) baseline (T0) and follow-up (T1) VRBQ Anxiety subscale; (v) T0 and T1 Geriatric Anxiety Inventory; (vi) T0 and T1 15-Item Geriatric Depression Scale; and (vii) the duration of BPPV symptoms (from onset to first repositioning manoeuvre) with follow-up (T1) VAS dizziness and unsteadiness scores, respectively. Each model included the following covariates: (i) how dizzy or unsteady the participants felt (baseline (T0) dizziness or unsteadiness VAS scores); (ii) the number of days from baseline (T0) to follow-up (T1); and (iii) the (T1) positional test result as quantified by the intensity of the nystagmus (slow phase velocity, SPV, °/s) measured during the test.

As the follow-up (T1) positional test nystagmus slow phase velocity (SPV) was missing at very low levels (n=2), the transcan function developed by Harrell (2015) was used to singly impute missing values. R version 1.1.456 (https://www.r-project.org/) was used for all statistical analyses and a *p* value of less than 0.05 was considered as statistically significant.

5.6 Results

5.6.1 Participant profile

A total of 40 participants with BPPV and 20 comparison control participants were recruited (see Table 5.1). Women made up 60% (12/20) and 75% (30/40) of the comparison control and BPPV groups respectively, however the difference in proportion of females between the groups was not statistically significant ($\chi^2(1) = 1.43$, $p = .23$). The participants recruited were aged between 55 years old to 83 years old. There was no significant age difference ($t(51) = -1.76$, $p = .08$) between the BPPV group ($M = 67.3$, $SD = 7.3$) and the comparison control group ($M = 64.4$, $SD = 5.1$). The BPPV group, however, had a significantly greater number of comorbidities (*Mdn* = 3.5), compared with the comparison control group (*Mdn* = 1) ($W = 181.5$, $p < .001$). Hyperlipidaemia, hypertension, and arthritis were the most common comorbidities amongst the participants. All participants were independent community ambulators with two participants from the BPPV group requiring the use of a walking stick for outdoor ambulation.

In the BPPV group, all participants had canalithiasis type of BPPV. The posterior canal was most affected as diagnosed in 33 participants (83%), followed by the horizontal canal (6/40, 15%) and the anterior canal (1/40, 2%). In addition to canalithiasis, two participants had concurrent cupulolithiasis. Four participants had bilateral BPPV. The chronicity of the condition was a median of 29.5 days at initial assessment (T0) (*IQR* = 10.5 – 54.3, 90th percentile 273.2 days). At T0, 14 out of 40 participants reported they took medication to help with their dizziness while only three participants required the use of medication at T1.

The number of falls in the BPPV group (*Mdn* = 0, *IQR* = 0 – 0, range = 0 - 3), in the six months prior to the onset of BPPV symptoms (premorbid), was not significantly different from that of the comparison control group (*Mdn* = 0, *IQR* = 0 – 0, range = 0 - 1) ($p = .408$, adjusted by age, gender, and number of comorbidities). Premorbid (within the six months prior to study entry (T0) and BPPV symptoms onset), the number of fallers in the comparison control group was two (10%) while the number of fallers in the BPPV group was seven (17.5%), $\chi^2(1) = 0.59$, $p = 0.44$, respectively. After the onset of BPPV up to baseline assessment (T0), the median number of falls for the BPPV group remained as 0 (*IQR* = 0 – 0, range = 0 - 1) with seven participants (17.5%) reporting having fallen during this period. Of these seven

participants, six did not report any falls during the six months prior to the onset of BPPV symptoms.

Table 5.1. Comparison of characteristics between the BPPV group and the comparison control group

Variable	Control (*N* = 20)	BPPV-T0 (*N* = 40)	*p* value
Age (years) *M* (SD)	64.4 (5.1)	67.3 (7.3)	.084*
Women *n* (%)	12 (60.0%)	30 (75.0%)	.232+
Marital status *n* (%)			.614+
Single	3 (15.0%)	6 (15.0%)	
Married	16 (80.0%)	28 (70.0%)	
Widowed	0 (0.0%)	3 (7.5%)	
Divorced	1 (5.0%)	3 (7.5%)	
Occupation *n* (%)			.097+
Not working/retired	9 (45.0%)	23 (57.5%)	
Working	11 (55.0%)	17 (42.5%)	
Social *n* (%)			.361+
Living alone	1 (5.0%)	5 (12.5%)	
Living with family	19 (95.0%)	35 (87.5%)	
Walking aid *n* (%)			.309+
Nil	20 (100.0%)	38 (95.0%)	
Walking stick for outdoor ambulation only	0 (0.0%)	2 (5.0%)	
No. of falls in the preceding 6 months (premorbid) (*Mdn, IQR,* range)	0 (0 - 0) (range 0 – 1)	0 (0 - 0) (range 0 – 3)	.414#
No. of fallers in the preceding 6 months (premorbid) *n* (%)	2 (10.0%)	7 (17.5%)	.443+
No. of falls (since BPPV symptoms onset) (*Mdn, IQR,* range)		0 (0 – 0) (range 0 – 1)	
No. of fallers (since BPPV symptoms onset) *n* (%)		7 (17.5%)	

Variable	Control (*N* = 20)	BPPV-T0 (*N* = 40)	*p* value
No. of comorbidities (*Mdn, IQR*)	1 (1 - 2)	3 (2 - 5)	< .001[@]
Hypertension	9 (45.0%)	20 (50.0%)	
Diabetes	2 (10.0%)	7 (17.5%)	
Hyperlipidaemia	6 (30.0%)	22 (55.0%)	
Heart diseases	1 (5.0%)	5 (12.5%)	
Depression	0 (0.0%)	1 (2.5%)	
Osteoporosis	0 (0.0%)	3 (7.5%)	
Arthritis	1 (5.0%)	13 (32.5%)	
BPPV Characteristics			
Canalithiasis *n* (%)			
Posterior Canal		33 (82.5%)	
Horizontal Canal		6 (15.0%)	
Anterior Canal		1 (2.5%)	
Cupulolithiasis (concurrent to Canalithiasis) *n* (%)		2 (5.0%)	
Bilateral BPPV *n* (%)		4 (10.0%)	
Chronicity (days) (*Mdn, IQR*, 90th percentile)		29.50 (10.5 – 54.3, 273.2)	

Note. M = mean; SD = standard deviation; Mdn = median; IQR = inter-quartile range.
*Independent samples t-test; [+]Chi-squared Test; [#]*p* value (adjusted by age, gender, and no. of comorbidities); [@]Mann-Whitney U Test.

5.6.2 Group comparison at baseline (T0) (BPPV and comparison control)

As shown in Table 5.2, the BPPV group scored significantly poorer ($p < .05$, adjusted for age, gender, and number of comorbidities) than the comparison control group, across all physical tests and questionnaires, except for the left and right horizontal vestibulo-ocular (VOR) gains, the Geriatric Anxiety Inventory, and the Geriatric Depression Scale Short Form – 15 items. The BPPV group tested slower in both maximum/fast walking speed and comfortable walking speed with horizontal head turns, when compared with that of the comparison control group.

For the Modified Clinical Test of Sensory Integration of Balance (mCTSIB), as it was part of the modified protocol, only 25 participants from the BPPV group and 16 participants from the comparison control group underwent this assessment. These subsets of participants from both groups were able to complete the maximum time of 30 seconds for the first three conditions: standing on firm surface with eyes open, firm surface with eyes closed, and foam surface with eyes open. For the last condition of standing on foam surface with eyes closed, the comparison control group performed significantly better, with all participants completed 30 seconds while the BPPV group had a median time of 16 seconds.

The BPPV group had significantly higher Vestibular Rehabilitation Benefits Questionnaire (VRBQ) Total, Anxiety, and Quality of Life scores (percentage deficits) compared with the comparison control group. The Activities-specific Balance Confidence scale (ABC) score was significantly higher in the comparison control group compared to the BPPV group. Physical activity, as measured by the Human Activity Profile adjusted activity score (HAPAAS), was significantly lower in the BPPV group compared with the comparison control group.

Table 5.2. Comparison of outcomes between the BPPV group and the comparison control group at baseline (T0) with adjustment for age, gender, and number of comorbidities

Variable	Control (*N* = 20)	BPPV-T0 (*N* = 40)	*p* value
Fast walking speed (m/s)	1.74 (0.22) 1.55 **1.79** 1.90	1.37 (0.32) 1.26 **1.38** 1.59	.002
Comfortable walking speed with horizontal head turns (m/s)	**1.08 (0.16)** 1.02 1.05 1.14	**0.81 (0.22)** 0.70 0.79 0.95	.001
mCTSIB – Foam with eyes closed time (sec)	30.00 (0.00) 30.00 **30.00**[a] 30.00	17.02 (11.60) 7.00 **16.00**[b] 30.00	.002
Left Horizontal VOR gain	**1.0 (0.1)** 0.9 1.0 1.0	**1.0 (0.2)** 0.9 0.9[c] 1.0	.675
Right Horizontal VOR gain	**1.0 (0.1)** 0.9 1.0 1.1	**1.0 (0.1)** 1.0 1.0[c] 1.1	.453
VAS vertigo (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	54.8 (30.5) 33.5 **53.5** 80.0	< .001
VAS dizziness (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	34.0 (27.9) 8.8 **30.0** 50.0	< .001
VAS unsteadiness (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	35.3 (27.1) 20.0 **30.0** 50.0	< .001
VRBQ Total % deficit (0 - 100%)	1.5 (5.1) 0.0 **0.0** 0.2	25.7 (13.8) 15.4 **26.6** 34.2	< .001
VRBQ QOL % deficit (0 - 100%)	0.0 (0.0) 0.0 **0.0** 0.0	21.8 (20.0) 8.4 **18.2** 28.1	< .001
VRBQ Anxiety % deficit (0 - 100%)	0.0 (0.0) 0.0 **0.0** 0.0	7.5 (10.0) 0.0 **2.8** 11.1	.001
GAI (0 - 20)	2.1 (4.8) 0.0 **0.0** 1.3	4.2 (5.1) 0.0 **2.0** 6.0	.325[#]

Variable	Control (*N* = 20)	BPPV-T0 (*N* = 40)	*p* value
GDS-15 (0 - 15)	1.0 (1.3) 0.0 **0.5** 2.0	2.3 (2.4) 0.0 **2.0** 3.0	.078
ABC (0 - 100%)	97.3 (3.9) 96.1 **99.4** 100.0	81.0 (16.7) 75.0 **85.6** 91.9	.003
HAP MAS (0 - 94)	82.7 (8.9) 76.0 **82.0** 91.3	72.6 (12.9) 64.0 **74.0** 81.5	.038
HAP AAS (0 - 94)	79.3 (10.6) 72.0 **77.0** 88.3	64.2 (13.3) 59.5 **64.0** 71.5	.002

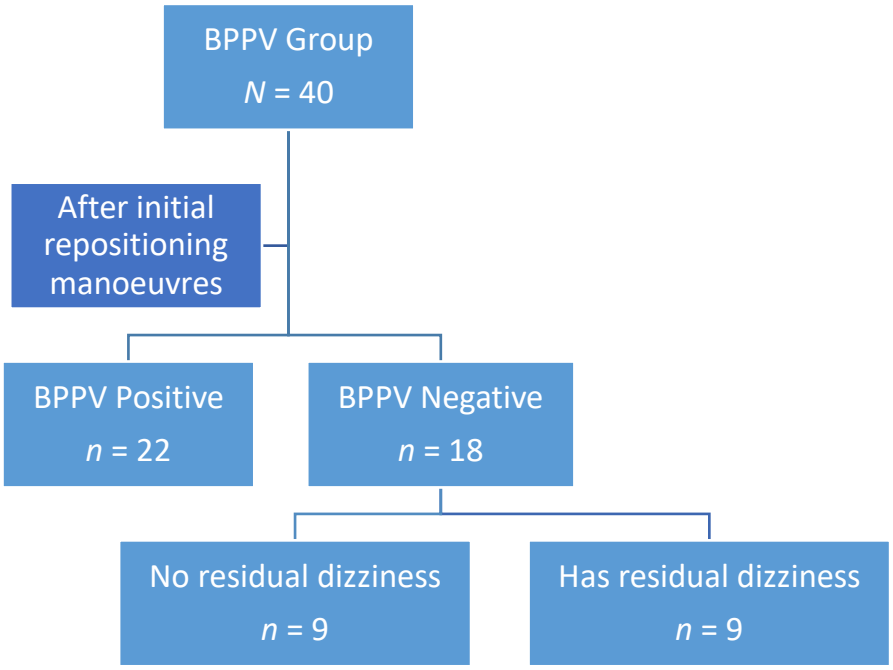
Note. Continuous variables are summarized as mean (SD) and 25th 50th and 75th percentiles. Bold values denote the representative measures of central tendency for the specific variables.

[a]*n* = 16; [b]*n* = 25; [c]*n* = 29; mCTSIB = Modified Clinical Test of Sensory Integration on Balance; VAS = Visual Analogue Scale; VRBQ = Vestibular Rehabilitation Benefits Questionnaire; GAI = Geriatric Anxiety Inventory; GDS-15 = 15-Item Geriatric Depression Scale; ABC = Activities-Specific Balance Confidence Scale; HAP = Human Activity Profile; MAS = Maximum Activity Score; AAS = Adjusted Activity Score.

5.6.3 Change in BPPV group and comparison of results with comparison controls at first follow-up (T1)

The median duration from baseline/study entry (T0) to first follow-up (T1) for the BPPV group was 7.0 days (*IQR* 6.8 – 10.0). At the first follow-up, after initial repositioning manoeuvres, 22 participants (55%) (mean age = 68.8 years old, *SD* = 7.2) in the BPPV group were found to be still positive on positional testing. Eighteen participants (45%) (mean age = 65.5 years old, *SD* = 7.1) tested negative on all positional tests (see Figure 5.2).

Figure 5.2 Diagram showing the BPPV status and distribution of participants after initial repositioning manoeuvres



5.6.3.1 Follow-up (T1) BPPV-positive group vs comparison control group

At the follow-up, 22 participants from the BPPV group remained positive when tested for BPPV. The mean age of these participants was 68.8 (7.2) years old. Comparing the results of the outcomes after initial repositioning manoeuvres with those of the comparison control group, the follow-up BPPV-positive group remained significantly poorer in the performance of the following outcomes ($p < .05$, adjusted for age, gender, and number of comorbidities): maximum/fast walking speed, VAS scores for vertigo and dizziness, VRBQ Total and Quality of life percentage deficits

scores, balance confidence (ABC), and physical activity level (HAP adjusted activity score). There was a significant difference in left vestibulo-ocular (VOR) gain between the groups, but the VOR gains for both groups were within normal limits (see Table 5.3).

Despite still requiring further repositioning manoeuvres, the follow-up BPPV-positive group achieved comparable results (no significant difference) to that of the comparison control group in some outcomes. The mean comfortable walking speed with horizontal head turns of the BPPV-positive group was 0.89 (0.22) m/s (Comparison control: M = 1.08, SD = 0.16, adjusted p = .164). There were only data of 11 participants in this group available on mCTSIB standing on foam with eyes closed. The test could not be performed at the follow-up sessions due to participants feeling unwell/dizzy, increased blood pressure, or time constraints - allowing only time to perform the primary outcome measures. There was no significant difference in the mCTSIB standing on foam with eyes closed time between the two groups. There were also no significant between-group differences for the following self-report measures: VAS unsteadiness, VRBQ Anxiety subscale and the Human Activity Profile Maximum Activity Score.

There was no significant difference in the number of falls between the two groups during the follow-up time. While none in the comparison control group fell in the follow-up period, two participants in the BPPV-positive group fell, with one of them sustaining two falls. Both participants had reported the falls happened when they felt vertiginous or dizzy.

Table 5.3. Comparison of outcomes between the follow-up BPPV-positive group (T1 BPPV-positive) and the comparison control group with adjustment for age, gender, and number of comorbidities

Variable	Control (*N* = 20)	T1 BPPV-positive (*N* = 22)	*p* value
Fast walking speed (m/s)	1.74 (0.22) 1.55 **1.79** 1.90	1.38 (0.28) 1.23 **1.45** 1.51	.010
Comfortable walking speed with horizontal head turns (m/s)	**1.08 (0.16)** 1.02 1.05 1.14	**0.89 (0.22)** 0.79 0.88 1.04	.164
mCTSIB – Foam with eyes closed time (sec)	30.00 (0.00) 30.00 **30.00**[d] 30.00	19.79 (11.95) 9.09 **29.33**[e] 30.00	.068
Left Horizontal VOR gain	**1.0 (0.1)** 0.9 1.0 1.0	**1.07 (0.17)**[f] 0.95 0.98 1.21	.036
Right Horizontal VOR gain	**1.0 (0.1)** 0.9 1.0 1.1	**1.09 (0.15)**[f] 0.98 1.08 1.19	.066
No. of falls during follow-up time	0.0 (0.0) 0.0 **0.0** 0.0	0.1 (0.5) 0.0 **0.0** 0.0	.646
No. of fallers during follow-up time *n* (%)	0 (0.0%)	2 (9.1%)	.167[+]
VAS vertigo (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	37.6 (32.4) 4.3 **35.0** 69.5	.003
VAS dizziness (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	33.9 (29.8) 10.0 **30.0** 50.0	.003
VAS unsteadiness (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	29.3 (32.1) 0.0 **20.0** 57.5	.072
VRBQ Total % deficit (0 - 100%)	1.5 (5.1) 0.0 **0.0** 0.2	18.0 (13.7) 8.4 **14.4** 26.2	.005

Variable	Control (*N* = 20)	T1 BPPV-positive (*N* = 22)	*p* value
VRBQ QOL % deficit (0 - 100%)	0.0 (0.0) 0.0 **0.0** 0.0	15.6 (17.3) 3.0 **13.7** 22.8	.021
VRBQ Anxiety % deficit (0 - 100%)	0.0 (0.0) 0.0 **0.0** 0.0	5.3 (9.8) 0.0 **0.0** 5.6	.054
GAI (0 - 20)	2.1 (4.8) 0.0 **0.0** 1.3	3.6 (6.0) 0.0 **0.0** 4.0	.870
GDS-15 (0 - 15)	1.0 (1.3) 0.0 **0.5** 2.0	3.1 (3.5) 1.0 **1.0** 4.0	.181
ABC (0 - 100%)	97.3 (3.9) 96.1 **99.4** 100.0	82.3 (13.1) 76.9 **83.1** 93.1	.013
HAPMAS (0 - 94)	82.7 (8.90) 76.0 **82.0** 91.3	72.9 (11.5) 64.0 **71.0** 82.0	.064
HAPAAS (0 - 94)	79.3 (10.6) 72.0 **77.0** 88.3	62.7 (17.5) 56.0 **62.0** 74.0	.017

Note. Continuous variables are summarized as mean (SD) and 25th 50th and 75th percentiles. Bold values denote the representative measures of central tendency for the specific variables.

[d]*n* = 16; [e]*n* = 11; [f]*n* = 14; mCTSIB = modified Clinical Test of Sensory Integration on Balance; VAS = Visual Analogue Scale; VRBQ = Vestibular Rehabilitation Benefits Questionnaire; GAI = Geriatric Anxiety Inventory; GDS-15 = 15-Item Geriatric Depression Scale; ABC = Activities-Specific Balance Confidence Scale; HAPMAS = Human Activity Profile maximum activity score; HAPAAS = Human Activity Profile adjusted activity score.

[+] = Chi-squared Test.

Further review of the outcome data between the BPPV-positive and comparison control groups was undertaken. As reported earlier, the models were adjusted for age, gender, and the number of comorbidities for the analyses of differences between the two groups. The difference between the estimated adjusted means (adjusted mean differences) between the two groups were generated for outcomes with non-significant results. The adjusted mean differences between the two groups (comparison control group adjusted mean minus BPPV-positive group adjusted mean) for the comfortable walking speed with horizontal head turns, Vestibular Benefits Questionnaire (VRBQ) Anxiety subscale, and Human Activity Profile maximum activity score (HAPMAS) are presented in Table 5.4.

For comfortable walking speed with horizontal head turns, the adjusted mean difference between the two groups was 0.10 m/s (95% CI [-0.04, 0.23]). For VRBQ Anxiety subscale, higher values indicate greater impairment. The adjusted mean difference between the comparison control and BPPV-positive groups was -5.3% (95% CI [-10.7, 0.1]). The adjusted mean difference between groups for HAPMAS was 7.4 (95% CI [-0.5, 15.2]). The minimal clinically important difference (MCID) for each of the outcomes are also presented in Table 5.4. The MCID for both comfortable walking speed and HAP were based on studies with various patient populations (Bohannon & Glenney, 2014; Chui, Hood, & Klima, 2012; Davidson & de Morton, 2007; Perera, Mody, Woodman, & Studenski, 2006) while that of VRBQ was based on adults with vestibular conditions (Morris et al., 2009).

No studies have investigated the MCID for comfortable walking speed with horizontal head turns. A study on comfortable walking speed with horizontal head turns and lateral body stability in community-dwelling older adults found that the normalised difference between self-selected walking speed and self-selected walking speed with head turns was 0.12 ± 0.12 (normalised to self-selected walking speed) (Singh et al., 2017). This result pointed to a relative difference of 12% between self-selected walking speed and self-selected walking speed with head turns in older adults. Given this information and that there are no available MCID on comfortable walking speed with horizontal head turns, hence the closest possible comparison was the MCID (0.1 m/s) for comfortable walking speed.

The adjusted mean differences for all three outcomes approximated the MCID or included the MCID in the corresponding 95% confidence intervals. The 95% confidence intervals included clinically significant differences. Hence, it is plausible that the true between-group differences are clinically significant, despite the statistically insignificant results. No MCID values are available to compare with the adjusted mean differences between groups for the Visual Analogue Scale (VAS) for unsteadiness and the mCTSIB standing on foam with eyes closed duration.

Table 5.4 Adjusted mean differences between T1 BPPV-positive and comparison control groups and MCID scores for comfortable walking speed with horizontal head turns and VRBQ Anxiety subscale

Outcome	Adjusted mean difference (Comparison control group – BPPV-positive group)	Lower CI	Upper CI	MCID
Comfortable walking speed with horizontal head turns (m/s)	0.10	-0.04	0.23	Comfortable walking speed 0.10 (Bohannon & Glenney, 2014; Chui et al., 2012; Perera et al., 2006)
VRBQ Anxiety (%)	-5.3	-10.7	0.1	5.0 (Morris et al., 2009)
HAPMAS	7.4	-0.5	15.2	MDC_{90} 7.8 MCID 11 (Davidson & de Morton, 2007)

Note. CI = confidence interval; VRBQ = Vestibular Rehabilitation Benefit Questionnaire; HAPMAS = Human Activity Profile maximum activity score; MDC_{90} = minimum detectable change (90% confidence); MCID = minimal clinically important difference.

5.6.3.2 Follow-up (T1) BPPV-negative group vs comparison control group

Comparing the participants in the BPPV-negative (n = 18) group with the comparison control group (n = 20) on all physical performance tests and questionnaires, no significant differences (p > .05, adjusted for age, gender, and number of comorbidities) were found between both groups for all measures (see Table 5.5). The mean age for the BPPV-negative (T1) group was 65.5 (7.1) years old. For mCTSIB standing on foam with eyes closed, data at follow-up (T1) was only available for 11 out of 18 participants from the BPPV-negative group. The reasons for the missing data are similar to that discussed under Section 5.6.3.1: participants felt unwell or tired, unforeseen situations i.e., increased blood pressure during the session, or were unable to stay the time required.

Table 5.5 Comparison of outcomes between the follow-up BPPV-negative group (T1 BPPV-negative) and the comparison control group with adjustment for age, gender, and number of comorbidities

Variable	Control (*N* = 20)	T1 BPPV-negative (*N* = 18)	*p* value
Fast walking speed (m/s)	1.74 (0.22) 1.55 **1.79** 1.90	1.48 (0.29) 1.31 **1.58** 1.69	.077
Comfortable walking speed with horizontal head turns (m/s)	**1.08 (0.16)** 1.02 1.05 1.14	**0.92 (0.19)** 0.86 0.94 0.99	.061
mCTSIB – Foam with eyes closed time (sec)	30.00 (0.00) 30.00 **30.00**[g] 30.00	23.73 (10.49) 19.66 **30.00**[h] 30.00	.103
Left Horizontal VOR gain	**1.0 (0.1)** 0.9 1.0 1.0	**0.94 (0.09)**[i] 0.92 0.95 0.99	.100
Right Horizontal VOR gain	**1.0 (0.1)** 0.9 1.0 1.1	**1.03 (0.14)**[i] 0.99 1.02 1.08	.907
No. of falls during the follow-up time	0.0 (0.0) 0.0 **0.0** 0.0	0.1 (0.2) 0.0 **0.0** 0.0	.086
No. of fallers during the follow-up time *n* (%)	0 (0.0%)	1 (5.6%)	.285[+]
VAS vertigo (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	8.1 (17.8) 0.0 **0.0** 7.5	.168
VAS dizziness (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	14.6 (25.0) 0.0 **0.0** 19.3	.115
VAS unsteadiness (0 - 100)	0.0 (0.0) 0.0 **0.0** 0.0	11.6 (26.8) 0.0 **0.0** 2.3	.345
VRBQ Total % deficit (0 - 100%)	1.5 (5.1) 0.0 **0.0** 0.2	11.8 (15.9) 1.9 **4.9** 13.9	.146

Variable	Control (*N* = 20)	T1 BPPV-negative (*N* = 18)	*p* value
VRBQ QOL % deficit (0 - 100%)	0.0 (0.0) 0.0 **0.0** 0.0	16.4 (23.9) 0.0 **6.1** 19.0	.091
VRBQ Anxiety % deficit (0 - 100%)	0.0 (0.0) 0.0 **0.0** 0.0	1.2 (4.1) 0.0 **0.0** 0.0	.554
GAI (0 - 20)	2.1 (4.8) 0.0 **0.0** 1.3	2.1 (3.0) 0.0 **0.0** 3.0	.442
GDS-15 (0 - 15)	1.0 (1.3) 0.0 **0.** 2.0	1.4 (1.3) 0.0 **1.0** 2.0	.815
ABC (0 - 100%)	97.3 (3.9) 96.1 **99.4** 100.0	89.6 (15.2) 90.8 **97.8** 98.8	.485
HAP MAS (0 - 94)	82.7 (8.9) 76.0 **82.0** 91.3	76.6 (10.3) 71.0 **75.5** 83.5	.273
HAP AAS (0 - 94)	79.3 (10.6) 72.0 **77.0** 88.3	68.9 (11.2) 61.0 **70.0** 75.0	.113

Note. Continuous variables are summarized as mean (SD) and 25th 50th and 75th percentiles. Bold values denote the representative measures of central tendency for the specific variables.

[g]*n* = 16; [h]*n* = 11; [i]*n* = 14; mCTSIB = modified Clinical Test of Sensory Integration on Balance; VAS = Visual Analogue Scale; VRBQ = Vestibular Rehabilitation Benefits Questionnaire; GAI = Geriatric Anxiety Inventory; GDS-15 = 15-Item Geriatric Depression Scale; ABC = Activities-Specific Balance Confidence Scale; HAP = Human Activity Profile; MAS = Maximum Activity Score; AAS = Adjusted Activity Score.

[+] = Chi-squared Test.

As with the differences in outcomes between the BPPV-positive and comparison control groups, the adjusted mean differences between groups were generated for the various outcomes. Not all outcomes have established MCID, standard error of measurement (SEM), or minimal detectable change (MDC). Presented in Table 5.6 are the outcomes with such known values, along with the respective adjusted mean differences between groups. The adjusted mean differences for maximum/fast walking speed and comfortable walking speed with horizontal head turns were 0.16 m/s (95% CI [-0.02, 0.33]) and 0.12 m/s (95% CI [-0.01, 0.24]), respectively. Higher VRBQ subscale scores indicated greater deficits. The adjusted mean differences between groups for the VRBQ Total, Quality of Life, and Anxiety subscales were -5.7% (95% CI [-13.6, 2.1]), -9.5% (95% CI [-20.7, 1.6]), and -0.6% (95% CI [-2.7, 1.5]), respectively. The adjusted mean differences for the Activities-specific Balance Confidence Scale (ABC) and HAP adjusted activity score (HAPAAS) were 2.4 (95% CI [-4.5, 9.3]) and 6.7 (95% CI [-0.6, 14.1]), respectively.

The only MCID available for maximum/fast walking speed was based on participants with Multiple Sclerosis (Coleman, Sobieraj, & Marinucci, 2012) and the value is very close to that of comfortable walking speed (0.11 m/s vs 0.10 m/s). No MCID score was available for ABC but a SEM of 1.197, based on community-dwelling older women aged 60 years and above, was available (Nemmers & Miller, 2008). The adjusted mean differences for most of the outcomes either approximated to the MCID or included the MCID within the 95% confidence intervals, except for VRBQ Anxiety subscale. Thus, the between-group differences for these outcomes plausibly are clinically significant, despite being statistically insignificant. For ABC, the adjusted mean difference and confidence intervals exceed the SEM, suggesting that the between-group difference in ABC did not occur due to measurement error.

Table 5.6 Outcomes with adjusted mean differences between T1 BPPV-negative and comparison control groups, and MCID scores

Measure	Adjusted mean difference (Comparison control group – BPPV-negative group)	Lower CI	Upper CI	MCID
Maximum/fast walking speed (m/s)	0.16	-0.02	0.33	0.10[#] (Bohannon & Glenney, 2014; Chui et al., 2012; Perera et al., 2006) 0.11[@] (Coleman et al., 2012)
Comfortable walking speed with horizontal head turns (m/s)	0.12	-0.01	0.24	0.10[#] (Bohannon & Glenney, 2014; Chui et al., 2012; Perera et al., 2006)
VRBQ Total (%)	-5.7	-13.6	2.1	7.0 (Morris et al., 2009)
VRBQ QOL (%)	-9.5	-20.7	1.6	9.0 (Morris et al., 2009)
VRBQ Anxiety (%)	-0.6	-2.7	1.5	5.0 (Morris et al., 2009)
ABC	2.4	-4.5	9.3	SEM 1.197^ (Nemmers & Miller, 2008)
HAPAAS	6.7	-0.6	14.1	MDC_{90} 6.8 MCID 14 (Davidson & de Morton, 2007)

Note. [#] Comfortable walking speed; [@] based on participants with Multiple Sclerosis;
^ Community-dwelling older women (aged ⩾ 60 years old).

CI = confidence interval; MCID = minimal clinically important difference; VRBQ = Vestibular Rehabilitation Benefit Questionnaire; QOL = Quality of Life; ABC = Activities-specifc Balance Confidence Scale; SEM = standard error of measurement; HAPAAS = Human Activity Profile adjusted activity score;
MDC_{90} = minimum detectable change (90% confidence).

5.6.4 Factors associated with residual dizziness

Nine participants in the T1-BPPV negative group were identified to have residual dizziness at follow-up (T1). They tested negative for BPPV on positional tests but reported ongoing symptoms of non-vertiginous dizziness and/or unsteadiness on the VAS scoring. To explore the factors associated with residual dizziness in the BPPV group (*N* = 40), two separate regression models were analysed using follow-up (T1) VAS dizziness or unsteadiness scores as dependent variables (see Table 5.7). The control variables used in the models were: baseline (T0) dizziness or unsteadiness scores, the number of days from baseline (T0) to follow-up (T1), and the follow-up (T1) positional test result as quantified by the nystagmus intensity (slow phase velocity, °/s).

For factors associated with dizziness at T1, age was a significant factor: every 10-year increase in age, there was a 14.8-point increase in the VAS dizziness score (ß = 14.8, 95% CI [4.1, 25.4], *p* = .008). Another significant factor was the number of comorbidities. An increase in one comorbidity would result in a 5-point increase in the VAS dizziness score (ß = 5.0, 95% CI [1.3, 8.7], *p* = .010). A one-point increase in the follow-up (T1) Geriatric Anxiety Inventory (GAI) score would yield a significant 1.7-point increase in the VAS dizziness score (ß = 1.7, 95% CI [0.1, 3.4], *p* = .038). The other variables were not significantly associated with the follow-up (T1) VAS dizziness score: baseline (T0) and follow-up (T1) VRBQ Anxiety scores, baseline (T0) GAI score, baseline (T0) and follow-up (T1) GDS-15 scores, the duration of BPPV symptoms, and being female.

For factors associated with unsteadiness at follow-up (T1), a 10 year-increase in age would result in VAS unsteadiness to increase by 17.6-points (ß = 17.6, 95% CI [6.7, 28.4], *p* = .002). The other three significant factors were the number of comorbidities, the follow-up (T1) VRBQ Anxiety score, and the follow-up (T1) GAI. An addition of one comorbidity would cause a 7.2-point increase; a 10% increase in the follow-up (T1) VRBQ Anxiety subscale would cause a 12.7-point increase; and a one-point increase in follow-up (T1) GAI score would yield a 1.9-point increase, in the follow-up (T1) VAS unsteadiness score, respectively. The other variables were not significantly associated with unsteadiness.

Table 5.7. Results of regression models exploring factors associated with residual dizziness at follow-up (T1) assessment (*N* = 40)

Factors	T1 VAS dizziness			T1 VAS unsteadiness		
	ß	95% CI	*p* value	ß	95% CI	*p* value
Age (10 years)	14.8	4.1 – 25.4	.008*	17.6	6.7 – 28.4	.002*
No of comorbidities	5.0	1.3 – 8.7	.010*	7.2	3.6 – 10.7	< .001*
Baseline (T0) VRBQ Anxiety score (10%)	-4.8	-13.9 – 4.2	.282	-5.1	-14.0 – 3.9	.258
Follow-up (T1) VRBQ Anxiety score (10%)	8.2	-3.7 – 20.0	.172	12.7	1.4 – 24.1	.028*
Baseline (T0) GAI	0.1	-1.5 – 1.7	.893	0.0	-1.7 – 1.7	.976
Follow-up (T1) GAI	1.7	0.1 – 3.4	.038*	1.9	0.1 – 3.6	.037*
Baseline (T0) GDS-15	2.7	-0.7 – 6.0	.115	0.4	-3.3 – 4.1	.831
Follow-up (T1) GDS-15	2.9	-0.1 – 5.9	.060	3.0	0.0 – 6.0	.050

Factors	T1 VAS dizziness			T1 VAS unsteadiness		
	ß	**95% CI**	***p* value**	**ß**	**95% CI**	***p* value**
Duration of BPPV symptoms (between 11 and 54 days)	4.8	-1.9 – 11.5	.156	3.7	-3.4 – 10.8	.299
Female gender	3.3	-15.3 – 21.8	.722	3.1	-16.8 – 23.0	.755

Note. All models were adjusted with the following covariates: (i) baseline (T0) VAS dizziness or unsteadiness scores; (ii) number of days to follow-up (T0 to T1); and (iii) follow-up positional test result quantified by positional nystagmus intensity (slow-phase velocity, °/s).

* = significant result at $p < .05$;

GAI = Geriatric Anxiety Inventory; GDS-15 = 15-Item Geriatric Depression Scale.

5.7 Discussion

This is one of the few prospective studies to explore ongoing residual dizziness and symptoms for older people with BPPV in the short term after repositioning manoeuvre treatment. Results highlighted a relatively low response to repositioning manoeuvres in resolving positional testing signs and symptoms relative to that reported for younger samples. Results also highlighted the ongoing issues for those with unresolved BPPV as well as residual impairments in those with resolved BPPV, after initial repositioning treatment.

Similar to previous studies (Kasse et al., 2012; Ribeiro et al., 2016; Teggi et al., 2011; Vaz et al., 2013), BPPV affected the older adults in this study in many ways: slower gait, decreased postural stability, decreased balance confidence, physical activity and quality of life, and increased anxiety. In this study, both the Geriatric Anxiety Inventory (GAI) and VRBQ Anxiety score were measured. While both GAI and VRBQ Anxiety percentage deficit were both in the lower score range, only the VRBQ Anxiety percentage deficit score exhibited a significant group difference. The reason might be that the GAI was designed to screen for generalised anxiety disorders (GAD) and symptoms in older adults (Pachana et al., 2007) and is not specific to the type of anxiety triggered by a transient medical condition such as BPPV. A recent study (Ozdilek et al., 2019) found that while participants with BPPV exhibited higher anxiety than control participants, they did not differ in health anxiety and somatic amplification levels. Health anxiety has been found to be associated with GAD and other comorbid mental conditions (Sunderland, Newby, & Andrews, 2013,) and is prevalent in older adults (El-Gabalawy, Mackenzie, Thibodeau, Asmundson, & Sareen, 2013). While patients with BPPV may not be at risk of developing health anxiety disorders due to its benign and transient nature, it is still important to monitor and screen for anxiety or negative emotions in older adults with BPPV, especially those with coexisting mental health conditions.

Falls data were collected for (a) prior to BPPV onset; (b) following BPPV onset to treatment; and (c) during the one-week follow-up. The data were compared to that belonging to a group of comparison controls of a similar age range. Vertigo/dizziness was found to be the most common reason of falls in older adults (Ganança et al., 2006). The results of this study, though not statistically significant, suggest that BPPV may increase the risk of falls in older people. There was an increase in the number of participants who fell following the onset of BPPV

symptoms. The number of older adults with BPPV who reported falls decreased following initial repositioning manoeuvres. However, there were still falls reported in both BPPV-positive and BPPV-negative groups, compared with none in the comparison control group falling in the same period. These findings highlight the need for close monitoring of falls and implementation of falls prevention measures in older adults with BPPV particular in the early treatment period. Other studies have also found that falls in older adults decreased with effective BPPV management (Gananca et al., 2010; Jumani & Powell, 2017). Nonetheless, part of the BPPV management should include educating older adults with BPPV on how the condition/symptoms may affect them and increase their risk of falls, and the possible preventive actions they can take. Concurrently, management should also include screening and correction for other falls risk factors.

After initial repositioning manoeuvres, just over half of the BPPV sample of older people had persistent positive positional tests at the first follow-up (T1). While some previous studies (Kao et al., 2009; Sato et al., 2013) have reported that repositioning manoeuvres were equally effective in both younger and older people, some studies have reported repositioning manoeuvres might not be as effective in older adults (Babac et al., 2014; Batuecas-Caletrio et al., 2013). Although this study did not find a significant age difference between those who remained BPPV-positive and those who were resolved of BPPV, one possible reason could be the small sample size of this study.

Of those who had BPPV resolution on follow-up, there were improvements in all physical and subjective measurements in the week after initial repositioning manoeuvres. There were no significant differences in the various measures between those in the BPPV-negative and the comparison control groups following repositioning treatment, with adjustment for age, gender, and number of comorbidities. A closer look at the data showed that the between group comparison *p* values for some measurements, such as walking speeds (maximum/fast walking speed and comfortable walking speed with horizontal head turns), postural stability (mCTSIB, foam with eyes closed), physical activity (HAPAAS), and quality of life (VRBQ QOL), were approaching statistical significance, and might have reached significance if the apriori sample size had been reached.

The BPPV-positive group at follow-up (T1) also demonstrated improvement in some results which were no longer significantly different from that of the comparison

controls. These outcomes included the comfortable walking speed with horizontal head turns, VRBQ Anxiety subscale, HAP maximum activity score, VAS unsteadiness score, mCTSIB standing on foam with eyes closed, and the mental health measures. These non-significant results ($p > 0.05$) at follow-up were further examined using the adjusted mean differences (and related confidence intervals) between groups. Not all outcomes have known MCID, SEM, or MDC values. For those outcomes with these available values, the adjusted mean differences approximated the corresponding MCID values. This points to these results being possibly clinically significant despite being statistically insignificant. Hence, further studies with larger sample sizes are required for more conclusive results.

In this study at follow-up (T1), the smallest effect size that a sample size of 38 (comprising both BPPV-negative and comparison control participants) could detect with 80% power was 0.935. Taking maximum/fast walking speed, with a pooled standard deviation of 0.26, as an example: based on an effect size of 0.935, the smallest between-group difference that the current analysis could detect was 0.24 m/s. This value exceeds both the minimal clinically important difference for walking speed and the between-group difference after adjustment for covariates. A larger sample size would have been useful in detecting the small but clinically important changes.

Of the 18 participants in the BPPV group who achieved negative positional tests at T1, nine were found to have residual dizziness. In this study, multiple regression models with adjustment of covariates were used to identify possible associations with residual dizziness (dizziness and unsteadiness). Four factors: age, the number of comorbidities, and both VRBQ Anxiety subscale and the Geriatric Anxiety Inventory at follow-up (T1), were found to be significantly associated with residual dizziness. The baseline (T0) VRBQ Anxiety subscale and Geriatric Anxiety Inventory were not significantly associated with residual dizziness at follow-up. It is important to note that causality is not established with these associations. Martellucci et al (2016) also identified age (> 65 years old) and anxiety as two factors associated with residual dizziness. However, the authors found that anxiety at time of diagnosis was useful in estimating the probability of residual dizziness. The finding from this study differs. One reason could be that different measures were used. In the study by Martellucci et al (2016), the Dizziness Handicap Inventory (DHI) was used, and anxiety was quantified by the emotional domain score. The questions used to survey

emotion/anxiety in both questionnaires were different, with the questions in the VRBQ more related with the somatic presentation of anxiety (i.e., shortness of breath, numbness, heart pounding) while those in the DHI are more directed towards how the person feels. Future studies incorporating factor analyses and comparisons of these dizziness-related questionnaires will be useful. Notwithstanding this, the findings in this study demonstrate the importance that clinicians monitor patient's level of anxiety at each visit and not just at the initial visit; especially if one is of advanced age and/or with multiple medical conditions.

It is well established that dizzy patients may become anxious and anxious people may experience dizziness (Staab & Ruckenstein, 2003). A recent study (Gunes & Yuzbasioglu, 2019) found that anxiety levels started to decrease one week after BPPV treatment and continued to improve at four weeks follow-up. However, when compared with healthy controls, some anxiety persisted in the BPPV group despite successful treatment. There is some evidence on the benefits of adjunct treatment such as mindfulness, cognitive behavioural therapy and other behavioural therapy in the successful management of patients who were dizzy and anxious (Honaker et al., 2013; Naber et al., 2011). Interdisciplinary collaboration and a holistic approach are integral. It is important to identify older adults with dizziness problems who exhibit any anxiety to find out more about their concerns and to provide the necessary management. This might be most important for older adults who live alone and do not have much social support, as a recent study (Duan et al., 2018) found that the amount of social support was independently associated with residual dizziness.

Limitations

A major limitation of this study is the small sample size. The apriori sample size estimate was 108 each for both BPPV and comparison control groups. Despite the measures and efforts taken to increase the recruitment numbers, the apriori sample size could not be achieved. The small sample size limited the number of variables that could be added to the regression model to minimise confounding. This is true for the model exploring factors associated with residual dizziness. It would have been ideal to add age, gender, and number of comorbidities (baseline) to the existing model. Austin and Steyerberg (2015) found that a minimum of 2 subjects per variable in the model was required to ensure an unbiased estimation of regression

coefficient in multiple regression, but larger numbers were needed for statistical power. Generally, the models in the cross-sectional analyses met the rule of thumb of 10 subjects per variable. The small sample size might be one reason why some variables were not found to be significantly associated with residual dizziness when they might be if the study was adequately powered. The small sample size could have also resulted in the lack of significant difference in the physical performance and questionnaire responses between the BPPV-negative and comparison control groups.

For the measurements used, the electronic VAS (for rating dizziness, vertigo, and unsteadiness) and the Chinese translation of VRBQ were not validated in this patient population before. This might affect the credibility of the results. Another limitation of the study is the lack of vestibular function tests such as the Vestibular Evoked Myogenic Potential test which would have provided a more comprehensive assessment of residual dizziness. As data collection took place in a clinical setting, there was a lack of control over test sequence, missing data secondary to patient refusals and/or medical reasons (i.e., poor tolerance, dizzy, increased blood pressure, rushing for time and neck problems). These limitations may affect the generalisability and conclusiveness of the results presented. No adverse events or harm took place during the study.

5.8 Conclusion

Older adults presenting with BPPV fared significantly poorer in gait, balance and balance confidence, and quality of life, compared with those without BPPV. Initial repositioning manoeuvres was not as effective in resolving BPPV in this sample of older adults, compared with other samples, often involving younger patient samples. For those who remained positive with BPPV after initial repositioning manoeuvres, there was a trend towards improvement in the outcomes. Less than half in the BPPV group tested negative on the first follow-up at approximately one week after initial repositioning manoeuvres. There were also no significant differences in all outcome results between this BPPV-negative group and the comparison control group. Closer examination of the non-significant results revealed the possibility of clinical significance in some outcomes such as the walking speed tests, VRBQ subscales, and HAP, despite the lack of statistical significance. Future studies with larger sample sizes are needed for more conclusive results.

Residual dizziness was observed in nine of the 18 older adults who were successfully treated. Age, the number of comorbidities, and the follow-up VRBQ Anxiety subscale and the Geriatric Anxiety Inventory, were found to be significantly related to residual dizziness. Older adults with BPPV in this study were more prone to falls. Falls monitoring, prevention measures, and education should be part of the management for this population, especially in the early treatment phase. The small sample size for this study may limit the generalisability and conclusiveness of the results. Future studies of better quality and larger samples are needed to further determine (a) the associated factors for residual dizziness; (b) the long-term psycho-emotional effects of BPPV; and (c) if early intervention for balance and gait deficits will be beneficial for older adults with BPPV.

The research reported in this chapter was partially supported by the SGH Research Grant - New Investigator Grant (SRG - NIG) (Grant number: SRG-NIG #10/2017; awarded to Dr Dawn Tan, Co-supervisor, and Principal Investigator (SGH).

Chapter 6 Longitudinal Study of Recovery from BPPV in Older Adults

6.1 Abstract

Benign Paroxysmal Positional Vertigo (BPPV) is most prevalent in older adults. Apart from the paucity of longer-term BPPV studies in older adults, residual dizziness in older adults with BPPV is also poorly understood. The aims of this longitudinal study were to track the changes in BPPV status, recurrence, and the number of falls over six months, and to identify factors and measures associated with residual dizziness, in older adults with BPPV. The follow-up time points started from a week post initial repositioning manoeuvres (T1); with the participants being followed up at one month (T2), three months (T3), and six months (T4). Comparison control participants were also monitored remotely for falls data over six months from study entry (T0; cross-sectional study 1). Data collected included both physical performance and self-report measures. Multilevel modelling regression analysis was used to explore the associations with residual dizziness. The participants included 40 older adults with BPPV and 20 comparison controls. At T1, 22 participants with BPPV (55%) remained positive while half of those who tested negative experienced residual dizziness. Over the six months follow-up, BPPV recurrence and residual dizziness were reported in six (15%) and 24 participants (60%), respectively. Age, anxiety, and depression were factors associated with residual dizziness in this group of participants. Residual dizziness was not significantly associated with gait, balance, or physical activity level; but was significantly associated with balance confidence, mental health, and quality of life. Although there was no significant difference in the number of falls between participants with BPPV and comparison controls, there was a trend of increased falls in the BPPV group, especially during the early period of rehabilitation. Residual dizziness and recurrence of BPPV are common in older adults with BPPV. Assessment and management of this patient group should be holistic to include domains such as physical/functional, mental health, and falls prevention.

6.2 Introduction

In the previous chapter, the cross-sectional studies investigated the short-term effectiveness of repositioning manoeuvres in older adults with BPPV; compared their physical and self-report measure performances with comparison controls; and explored the factors associated with residual dizziness. In this chapter, the longitudinal study is discussed in detail. Changes in BPPV status and BPPV recurrence over six months were explored. The study also investigated possible factors and measures associated with residual dizziness at six months in the same group of older adults with BPPV; and compared the number of falls between the BPPV and comparison control groups.

BPPV is a condition that can often be effectively treated with repositioning manoeuvres (Monobe, 2001; Rodrigues et al., 2018). Spontaneous recovery of BPPV may be possible in 20-80% of cases but may take weeks to months (Salvinelli et al., 2004; Sekine et al., 2006; Seo et al., 2007). Studies have shown resolution of BPPV is more effective and faster with treatment using repositioning manoeuvres when compared with either no treatment or the use of medications (Salvinelli et al., 2004; Seo et al., 2007; Woodworth et al., 2004; Yimtae et al., 2003). In the literature, the efficacy of repositioning manoeuvres is often based on a positive to negative positional test conversion and/or amelioration of vertigo. Some studies found that repositioning manoeuvres are effective in the treatment of BPPV in the short term but lack similar evidence in the longer term (Amor-Dorado et al., 2012; Nunez et al., 2000; Sherman & Massoud, 2001). This contrasts with other studies that found repositioning manoeuvres are effective in both short- and long-term (Bruintjes, Companjen, van der Zaag-Loonen, & van Benthem, 2014; Lopez-Escamez et al., 2005; Mantello et al., 2011; Prokopakis et al., 2005; Sridhar et al., 2003). One systematic review of 12 studies concluded that repositioning manoeuvres are effective both in the short term (< three months) and long term (> three months) (Rodrigues et al., 2018). However, long-term effectiveness was only reported by half of the studies and ranged from 55% to over 90%. Recurrence rate also ranged widely from 6% to 36% and was measured over different time periods.

Apart from positional vertigo, a person with BPPV may also experience problems with postural stability. For older adults, BPPV-related vertigo and balance problems further increase their risk of falls (Ganança et al., 2006; Lawson et al., 2008; Oliva Domínguez et al., 2005). A study by Oghalai et al (2000), on 100

patients seen at a geriatric clinic, found that 61% had unreported dizziness problems and nine percent had BPPV (previously undiagnosed). The same study also found that older adults with BPPV were 6.5 times more likely to experience falls compared with those without BPPV.

Participants with BPPV have demonstrated improvement in postural stability after repositioning manoeuvres (Celebisoy et al., 2008), including older adults (Kasse et al., 2012; Vaz et al., 2013). However, several studies reported different findings – for example, balance improved but was not sustained or did not achieve normal range at follow-up (Di Girolamo et al., 1998; Lanca et al., 2013). In addition, older adults did not improve in all aspects of balance post repositioning manoeuvres (K. M. Ribeiro et al., 2017; Silva et al., 2016); and were less likely to achieve normal balance, compared with younger adults (Blatt et al., 2000). Generally, there are few studies investigating the physical and mental health impacts of BPPV and its management. The most frequently used outcomes in the literature on BPPV are the positional tests and subjective symptom reports. Hence the success of BPPV treatment is often determined solely based on these outcomes. Nevertheless, outcomes pertaining to physical function and mental health are equally important in determining the extent of recovery from BPPV. Longitudinal data on the impact of BPPV and its sequalae on mobility, balance, mental health, and falls will be useful in the evaluation and enhancement of current BPPV management.

Residual dizziness, post repositioning manoeuvres and BPPV resolution, can be experienced in the form of light-headedness and/or feeling of unsteadiness in the absence of positional vertigo (N. H. Lee et al., 2009; Seok et al., 2008; Teggi et al., 2011). The current evidence for the prevalence and duration of residual dizziness varied across studies. The prevalence of residual dizziness ranged from 31% to 63% (Abou-Elew et al., 2011; Faralli et al., 2016; Seok et al., 2008; Teggi et al., 2011; Teggi et al., 2013). The duration of residual dizziness reported ranged from days to months (Seok et al., 2008; Teggi et al., 2011; Teggi et al., 2013). Moreover, not all studies included a follow-up phase and if they did, the follow-up time differed from study to study. The scarce evidence on residual dizziness in older adults with BPPV, compared with the general BPPV population, warrants further research investigation.

Though BPPV is not usually a chronic problem, it is known to be recurrent. The prevalence of BPPV recurrence had been reported to range from 15% per year with 50% in 40 months (Nunez et al., 2000) to up to 50% in 10 years (Brandt,

Huppert, Hecht, Karch, & Strupp, 2006). A recent large study (Luryi et al., 2018) found that approximately 50% of recurrences happened in the first year after BPPV resolution. Some studies suggested that older adults were more likely to experience recurrence (Batuecas-Caletrio et al., 2013; Kao et al., 2009), yet others reported there was no association between age and recurrence (Nunez et al., 2000; Pérez et al., 2012; Sakaida, Takeuchi, Ishinaga, Adachi, & Majima, 2003). The systematic review conducted as part of this PhD series of studies (as presented in Chapter 3) did not find a significant difference in the BPPV recurrence rate between younger (<60 years old) and older adults (≥60 years old) but reported the finding as inconclusive. One major contributing factor could be that most studies in the older adult group included participants of various ages (≥18 years old), although the review criteria for classification of a sample as "older" was that the sample had an overall mean/median age of ≥60 years old. There were few studies involving a population completely comprised of older adults. In addition, only one out of the four studies involving solely older adults investigated recurrence.

6.3 Objectives

To address the above-discussed issues, the aims of this study were:

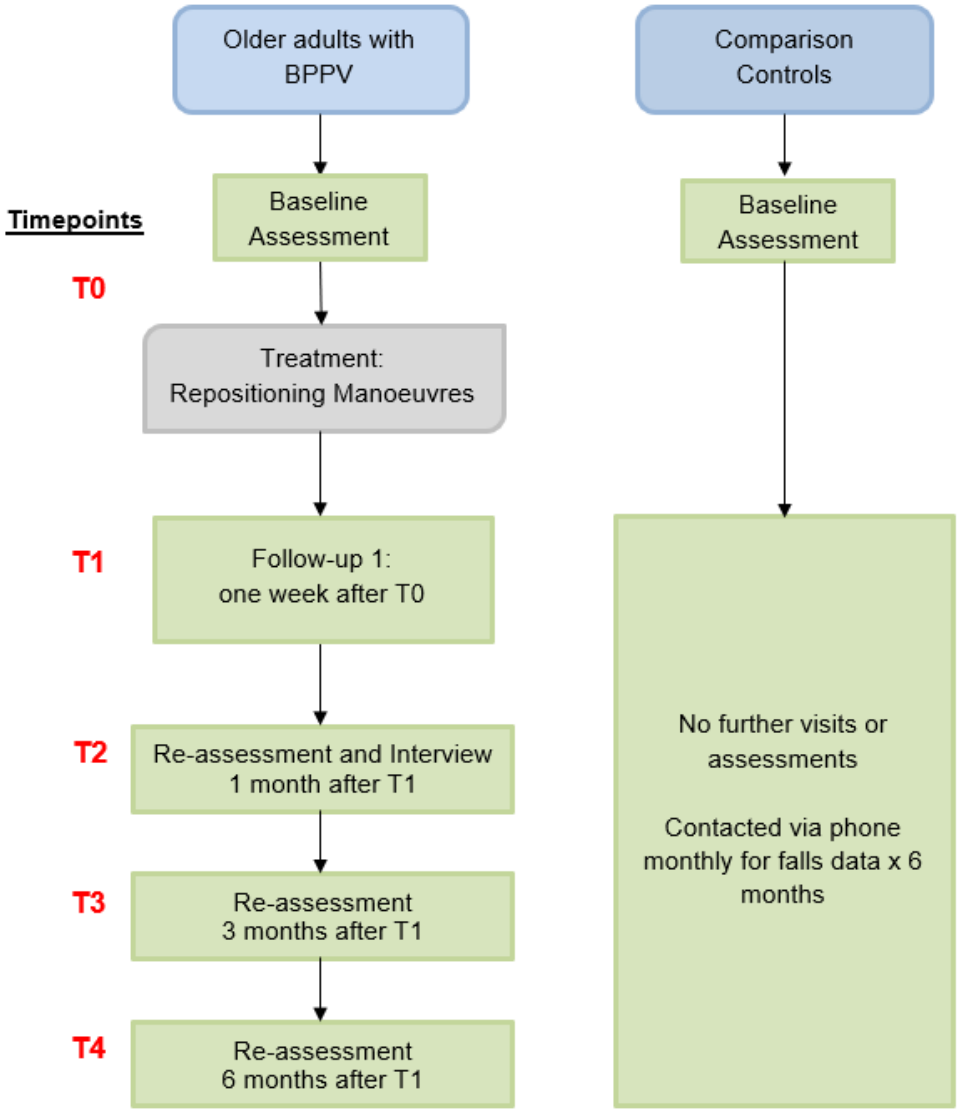
1. To identify the factors associated with residual dizziness and unsteadiness in older adults who were treated for BPPV at six-month follow-up.
2. To identify the physical/functional and self-report measures associated with residual dizziness and unsteadiness in older adults who were treated for BPPV at six-month follow-up.
3. Evaluate trends of recurrence and changes in BPPV status in older adults with BPPV over six months follow-up.
4. To conduct an exploratory investigation of whether older adults with BPPV experience more falls compared with comparison controls, over the six month period following repositioning treatment.

6.4 Methods

For the BPPV group, the longitudinal follow-up began at Follow-up 1 (T1) after initial repositioning treatments had been applied (see Figure 6.1). Four follow-up visits were allocated over six months: the first follow-up was planned to occur at one-

week post study entry (T1), the second follow-up (T2) at one month post follow-up 1 (T1), the third follow-up (T3) at three months post T1, and the final follow-up (T4) at six months post T1. All visits were planned to take place at the Singapore General Hospital (Singapore).

Figure 6.1 Diagram of longitudinal study timelines



At every follow-up, participants in the BPPV group underwent the same suite of assessment procedures as detailed in Chapter 4 (Methods). Briefly, these included:

Physical measures on BPPV status; gait; balance; and vestibular function:

- BPPV status (being BPPV positive or negative - commonly used terminologies in clinics) are usually determined through positional test responses: presence of the classic nystagmus and subjective symptom reporting of vertigo. In this study, the slow phase velocity (SPV) of the nystagmus recorded during the positional tests was also measured and recorded. The SPV was used, in the regression models, as a proxy measure instead of the usual binary status (positive or negative) or BPPV diagnoses. Using SPV (a continuous measure) has the advantages of not requiring a bigger sample size, and minimising information loss in the data, over the other two categorical measures.
- Modified Clinical Test of Sensory Integration on Balance (mCTSIB) (Cohen et al., 1993; A. Shumway-Cook & Horak, 1986) (added after protocol revision).
- Dynamic Gait Index (Anne Shumway-Cook & Woollacott, 1995) (Initial protocol only; not used in analysis).
- The Video Head Impulse Test (vHIT) (MacDougall et al., 2009).
- Comfortable walking speed (Middleton et al., 2015) (Initial protocol only; not used in analysis).
- Comfortable walking speed with horizontal head turns (A. Shumway-Cook et al., 2013) (added after protocol revision).
- Maximum/fast walking speed (Middleton et al., 2015).

<u>Self-report measures on symptoms intensity; impact of disease; balance confidence; physical activity level; and mental health</u>:

- Visual Analogue Scale (dizziness, vertigo, and unsteadiness intensities).
- The Vestibular Rehabilitation Benefits Questionnaire (VRBQ) (Morris et al., 2009).
- The Activities-specific Balance Confidence Scale (ABC) (Powell & Myers, 1995).
- The Human Activity Profile (HAP) (Daughton et al., 1982).
- The Geriatric Anxiety Inventory (GAI) (Pachana et al., 2007).
- The 15-item Geriatric Depression Scale (GDS-15) (Yesavage & Sheikh, 1986).

If a participant was unable or unwilling to return to the clinic for the full assessment, they were contacted for a phone interview to complete the questionnaires, as well as obtain data on falls and subjective ratings of dizziness,

vertigo, and unsteadiness. As this was an observational study in a clinical setting, whether the participants with BPPV continued physiotherapy (including the types of treatment prescribed) were determined by the clinicians. Generally, the participants would carry on receiving treatment if they continued to test positive for BPPV. They might also be prescribed home exercises such as the Brandt-Daroff exercises and Vestibular Rehabilitation exercises (balance, habituation, and gaze stability). From the medical records, 19 (48%) participants were prescribed with balance exercises while 12 (30%) were prescribed with gaze stability/habituation exercises. Of these participants who had more than repositioning manoeuvres, 10 participants were given both balance and gaze stability/habituation exercises.

All participants were given a Falls Calendar to monitor for falls and were asked to record the details on the corresponding date if they experienced a fall (see standard definition used, Chapter 4, section 4.4.9). In addition, they were contacted monthly by the researcher, who checked on their symptoms and falls records. If a participant complained of positional vertigo and was in between follow-ups, he or she would be invited to return for an additional assessment and treatment (if appropriate). However, the decision to return for the additional assessment was left up to the participant.

For the comparison control group, the follow-up began at study entry and lasted for six months (see Figure 6.1). The participants in the control group were not required to return after the initial assessment for any formal assessment. They were only monitored remotely for falls during the follow-up six month period. The comparison controls were given a Falls Calendar each and contacted monthly for the falls record.

6.5 Statistical Analysis

6.5.1 Missing data management

This section discusses the operational measures undertaken to determine BPPV status when positional tests could not be performed, and to manage missing data.

In tracking the trends of recurrences and changes in BPPV status over six months, it was planned for participants to be assessed for BPPV (positional tests) at each follow-up. However, there were situations when the positional tests could not be administered and the BPPV status could not be confirmed: (i) when participants

were not present for physical assessments but had completed the subjective assessments; (ii) when participants had refused to undergo positional tests; and (iii) when the doctor had ordered for positional tests to be held off for a participant. In these cases, assignment of BPPV status were based on clinical judgement derived from close examination of the subjective outcomes and history taking.

The following were scenarios when positional tests could not be done: (i) if the participant reported being well physically (VAS vertigo, dizziness and unsteadiness scores were zeros) and functioning as per premorbid, he/she was assigned a BPPV status of being negative; (ii) for participants who reported some vertigo/dizziness with corroborating functional disturbances and who were positive at the prior follow-up, the status remained as positive.

The last operational BPPV status was residual dizziness. Participants were assigned “residual dizziness” status when they reported dizziness and/or unsteadiness, quantified by VAS self-rating, and tested negative on positional tests. When positional tests could not be performed, “residual dizziness” was assigned when dizziness and/or unsteadiness were present in the absence of vertigo (quantified by VAS self-rating for all three sensations). This would be ascertained with corroborating history. Recurrence was defined as “a change in BPPV status, quantified by positional test(s), from a prior “negative” (with or without residual dizziness) to “positive” as at the time of testing.

This was a longitudinal study with four assessment timepoints for every participant. There was a total of 40 older participants with BPPV. Data collected consisted of both level one (clustered observations within individual participants) and level two (individual participants) variables. Of the expected 160 observations (40 participants x 4 follow-ups), a total of 154 observations were obtained as there were six unfulfilled follow-ups. These six missing observations were not considered for the imputation of missing data. Of the 32 variables, 12 had missing values with proportions of missing data ranging from 1% to over 50% (see Table 6.1). As a result, 58% of the observations had at least one piece of missing data. The variable with the most missing values was the modified Clinical Test of Sensory Integration on Balance (mCTSIB) assessment. In Chapters 4 and 5, it was reported that a change in protocol was implemented after the first 15 participants with BPPV were recruited. The mCTSIB was added with the protocol change. Hence, the first 15 participants did not undergo this test at all.

In addition, together with the other variables such as the slow phase velocity (SPV) of nystagmus (measured during positional tests for BPPV) and the binary BPPV status (positive or negative for positional tests), the missing data could be attributed to (i) participants had refused or were unable to undergo the assessment(s); and/or (ii) the follow-up assessments were conducted via phone calls. The maximum/fast walking speed test had missing values for observations with follow-ups conducted over phone. The other walking speed test (comfortable walking speed with horizontal head turns) had missing values secondary to (i) follow-up assessments being conducted over the phone; and (ii) data captured on the GAITrite® system for the first 15 participants being incomplete: The space where the GAITrite® mat could be set out was not always available for use and there were no other areas available due to space constraints.

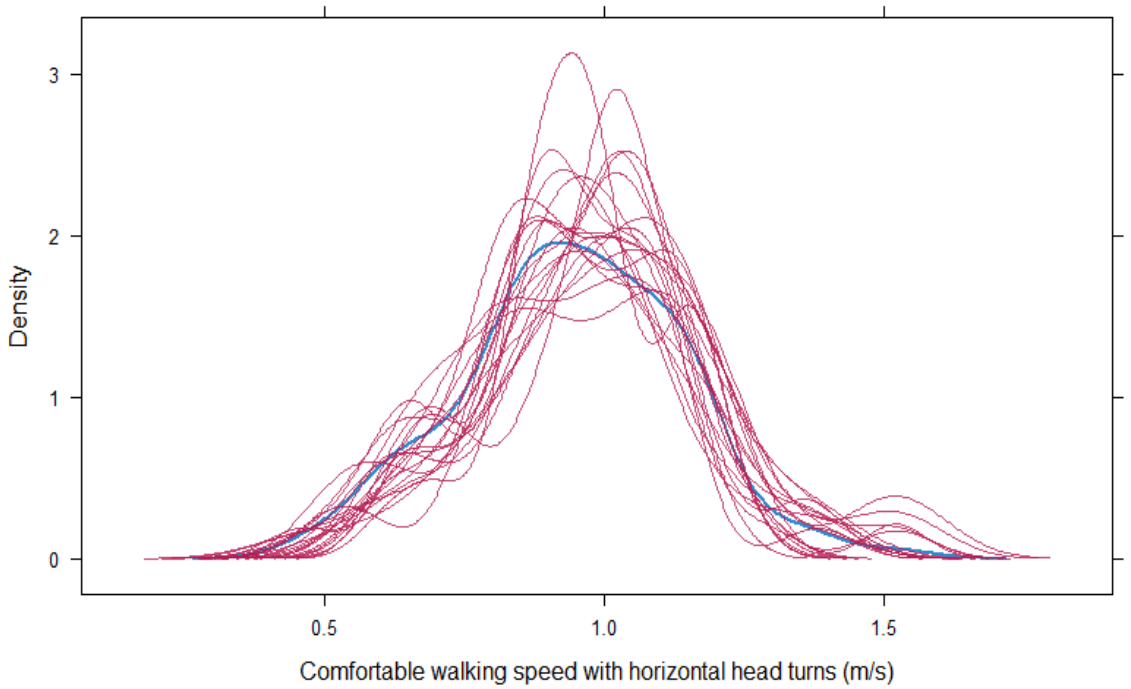
Table 6.1 Table of proportion of missing data of variables (out of 154* observations for each variable)

Variable	Missing number of observations	Percentage (%) missing
Maximum/fast walking speed (m/s)	18	11.7
Comfortable walking speed with HHT (m/s)	34	22.1
Slow phase velocity (°/s)	26	16.9
Positional test result (Positive/Negative)	25	16.2
HAPAAS	2	1.3
ABC	2	1.3
Geriatric Anxiety Inventory	2	1.3
15-Item Geriatric Depression Scale	2	1.3
mCTSIB - FIRMEO (sec)	85	55.2
mCTSIB – FIRMEC (sec)	85	55.2
mCTSIB – FOAMEO (sec)	85	55.2
mCTSIB – FOAMEC (sec)	85	55.2

Note. *154 observations, as six missed follow-ups were not considered for missing data for the purpose of imputation. HHT = horizontal head turns; HAPAAS = Human Activity Profile adjusted activity score; ABC = activities-specific balance confidence scale; mCTSIB = modified Clinical Test of Sensory Integration on Balance; FIRMEO = standing on firm surface with eyes open; FIRMEC = standing on firm surface with eyes closed; FOAMEO = standing on foam with eyes open; FOAMEC = standing on foam with eyes closed.

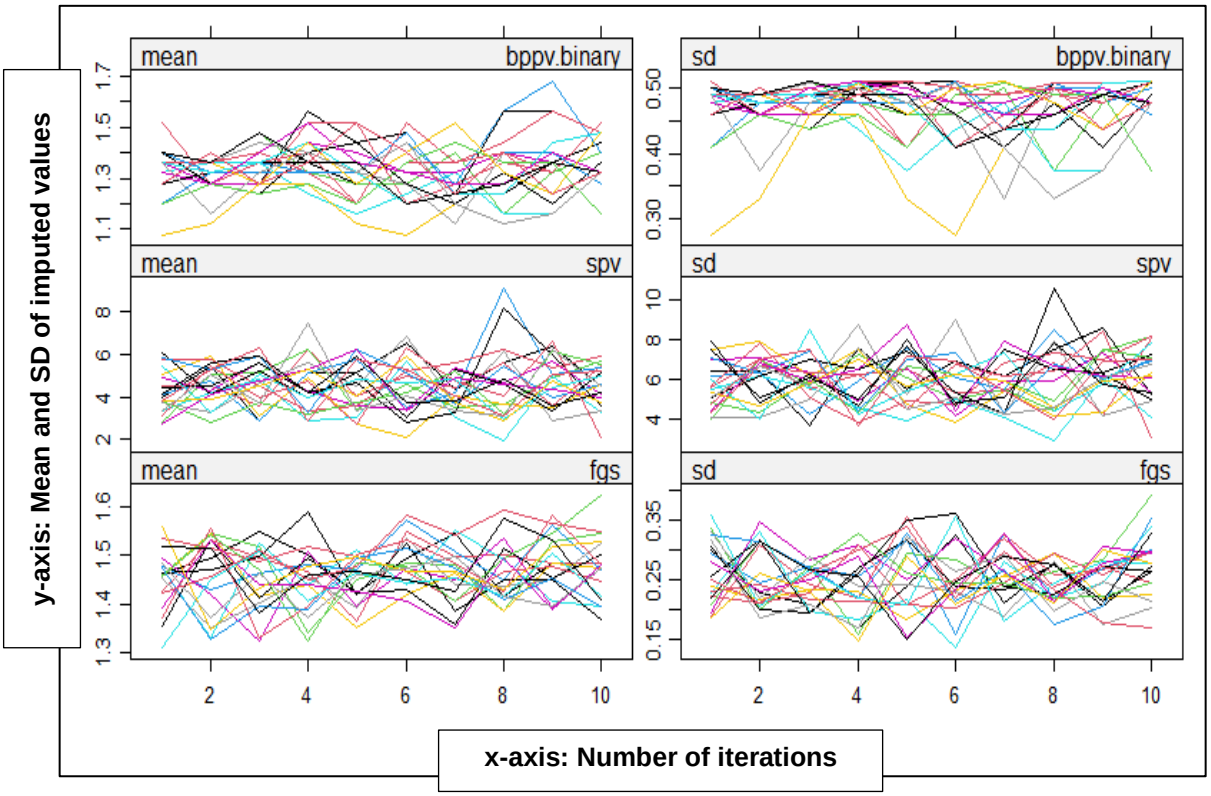
To minimize selection bias from missing data and assuming data were missing at random, multiple imputation was performed using the Multiple Imputation by Chained Equations (MICE) package (version 3.9.0) (Buuren & Groothuis-Oudshoorn, 2011) of the R statistics software (version 4.0.1) (F. E. S. Tan, Jolani, & Verbeek, 2018). Utilising multi-level predictive mean matching (2l pmm), 20 imputed datasets were created and analysed. An examination of the density plots showed similar distributions for both original and imputed values (see Figure 6.2 for an example). Examination of convergence plots revealed convergence of all variables (see Figure 6.3 for plots on positional test result [BPPV binary status - positive/negative], slow phase velocity, and maximum/fast walking speed). The estimates and standard errors from each imputed dataset were then pooled using Rubin's rules (Rubin, 1987).

Figure 6.2 Density plot showing distribution of both original and imputed values for comfortable walking speed with horizontal head turns



Note. Blue = observed values; Red = imputed values.

Figure 6.3 Convergence plots for positional test result (positive/negative), the slow phase velocity, and maximum/fast walking speed – showing the mean and standard deviations of the imputed values against the number of iterations for the imputed data



Note. bppv.binary = positional test result (positive/negative); spv = slow phase velocity (°/s); fgs = maximum/fast gait speed (m/s).
A good convergence plot should show the different streams intermingling freely without a definite trend.

6.5.2 Data analysis

As this was a longitudinal study with four follow-up timepoints for all participants, analyses were performed using linear mixed effects models to account for both random and fixed effects. To explore associations with residual dizziness and unsteadiness, separate models were generated with dizziness (VAS dizziness score) and unsteadiness (VAS unsteadiness score) as dependent variables (also known as outcome variables), respectively. The models included random intercept and random time slope for each participant to allow the baseline responses and the time slopes to vary between participants. The fixed effects terms such as age, gender, number of comorbidities (at baseline), the slow phase velocity of positional

nystagmus (as a proxy for BPPV status), and the actual number of weeks (calculated from T1) were used in the models for covariate adjustment. Fixed effects terms explored for their associations with residual dizziness and unsteadiness included age; gender; anxiety (measured by the VRBQ Anxiety subscale and the Geriatric Anxiety Inventory separately); symptom duration (from initial onset of BPPV symptoms to initial treatment); previous history of BPPV; the 15-Item Geriatric Depression Scale (GDS-15); and living arrangements (alone or with family).

Multilevel modelling was also used to explore physical and self-report measures associated with dizziness, and unsteadiness. Models were generated separately with various physical and self-report measures as the dependent variables. The functional outcomes included maximum/fast walking speed, comfortable walking speed with horizontal head turns, and the modified Clinical Test of Sensory Integration on Balance (mCTSIB) standing on foam with eyes closed (FOAMEC) test. The reason why only the last condition of mCTSIB was included because this was the only condition the older adult participants with BPPV had difficulty with. The self-report outcomes included the Activities-specific Balance Confidence scale (ABC), the Vestibular Rehabilitation Benefits Questionnaire (VRBQ Total and Quality of life summary scores, and Anxiety subscale), the Human Activity Profile Adjusted Activity Score (HAPAAS), the Geriatric Anxiety Inventory (GAI), and the 15-Item Geriatric Depression Scale (GDS-15). VAS dizziness and unsteadiness scores were used as independent variables in separate regression models. The random effects term used was the number of weeks between follow-ups as per earlier models. Covariate adjustment was achieved by including the following fixed effects terms: age, gender, the number of comorbidities (at baseline), the slow phase velocity of positional nystagmus (as a proxy for BPPV status), and the actual number of weeks (calculated from T1).

For all the above-discussed regression analyses, age was modelled nonlinearly as a 3-knot restricted cubic spline (Harrell, 2015). Except for age, the regression coefficients were rescaled to the interquartile range (IQR) of the respective continuous independent variables. By doing so, it provides for a more standardised and meaningful comparison instead of the commonly used “one-unit change” (Babyak, 2009).

Participants from both BPPV and comparison control groups were tracked for falls monthly for six months. For the exploratory analysis of the total number of falls

between the BPPV and comparison control groups over six months, negative binomial regression was performed with previous history (number) of falls as covariate.

For descriptive statistics, the mean and standard deviation, and 25th, 50th, and 75th percentiles are presented. Continuous data were examined for normal distribution and presented accordingly. R version 4.0.1 (https://www.r-project.org/) was used for all statistical analyses. A *p* value of less than 0.05 was considered as statistically significant. The sample size calculation for the longitudinal study was discussed in the Methods chapter (Chapter 4, section 4.5).

6.6 Results

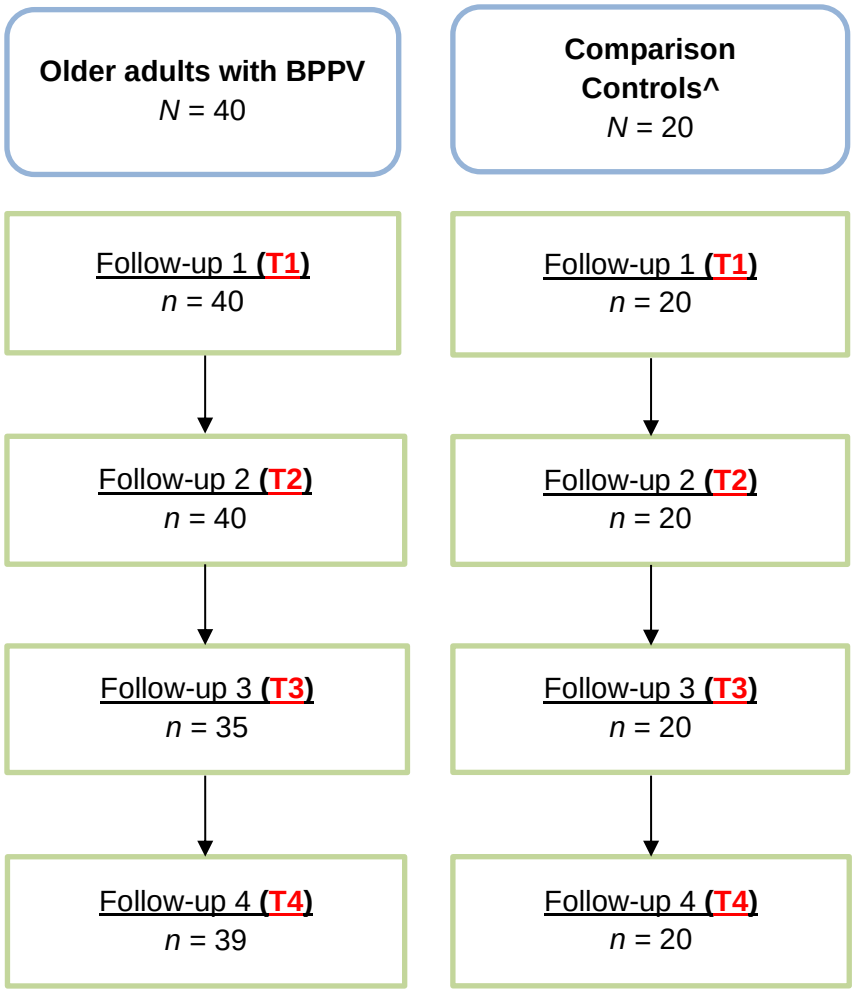
6.6.1 Overview

The longitudinal study started with 40 participants in the BPPV group and 20 participants in the comparison control group at T1 (see Figure 6.4). The participants from the comparison control group were followed up for collection of falls data over six months. There was no drop-out from the comparison control group. For the BPPV group, one participant refused to participate in the final two follow-ups (T3 and T4) citing he was busy. In addition, there were another five participants who were not available at T3 but participated in the final follow-up (see Table 6.2). There were six, seven and five participants who were not available for physical assessments but completed the subjective assessments at T2, T3, and T4 respectively (see Table 6.2).

For the BPPV group, the mean age was 67.3 years (*SD* = 7.27) and 75% were females. Twenty-seven participants (67.5%) had previous history of BPPV. The most common comorbidities amongst the group were hyperlipidaemia (55.0%), hypertension (50.0%), arthritis (32.5%), and diabetes (17.5%) (see Chapter 4 Table 4.1). At T1, as presented in Chapter 4, there were 22 participants who remained positive with BPPV, and 18 participants who tested negative on positional tests after initial repositioning manoeuvres. Of the 18 participants who tested negative, nine reported symptoms of residual dizziness as quantified by the VAS dizziness and unsteadiness scores. As previously reported in Chapter 4, three out of 40 participants required medication for their dizziness at T1. Subsequently, no participants required any medication at T2 and T3. Only one participant, who had a BPPV recurrence, took medication for dizziness at the final follow-up (T4). The

results for the physical performance and self-report outcomes of these three BPPV subgroups are presented in Table 6.3.

Figure 6.4 Number of participants for both BPPV and comparison control groups at each follow-up for this longitudinal study



Note. ^The comparison control participants were followed up remotely via phone calls for falls data only.

Table 6.2 Table of complete and subjective only assessments, and missing cases at various timepoints for BPPV group

Timepoint	T1	T2	T3	T4
Full assessment	40	34	28	34
Subjective assessment only	0	6	7	5
No of missing cases	0	0	5	1
Total	40	40	40	40

6.6.2 Changes in BPPV status and recurrences

Tracking the participants from the BPPV group over six months, the alluvial plot (see Figure 6.5) illustrates the changes in BPPV status throughout the longitudinal study for all the participants. The general trend was that the proportion of participants, who tested positive for BPPV, decreased over time. This corresponded with the increasing proportion of participants who tested negative and without residual symptoms over six months. The proportion of participants who tested negative but had residual dizziness remained similar throughout the study. At T1, there were 18 participants who tested negative (including nine who reported residual dizziness) and 22 participants remaining positive. At T2, 12 participants tested positive for BPPV. Twenty-eight participants tested negative for BPPV (including 10 with residual dizziness). At T3, eight participants tested positive for BPPV with 17 participants being negative and fully well. Another 10 participants were negative but had residual dizziness. At T4, four participants tested positive with 35 participants tested negative (including 10 with residual dizziness) for BPPV.

Overall, two participants had persistent BPPV that were not amenable to treatment (repositioning manoeuvres and Brandt-Daroff exercises). Three participants had also tested positive of BPPV for the first three follow-ups and were cleared of BPPV only on the last follow-up. Nine participants were cleared of BPPV during initial follow-ups (T1 and T2) and remained negative, fully asymptomatic, through the rest of the study. Over the entire study period, by relevant history and positional tests, six participants (15%) were confirmed to have experienced BPPV recurrences. Twenty-four participants (60%) reported residual dizziness at various points of the study, inclusive of five who experienced recurrences.

Table 6.3 Results of physical and self-report outcome measures for the BPPV sub-groups at T1 (start of longitudinal study)

	Positive (*n* = 22)	**Negative (*n* = 9)**	**Negative, but had residual dizziness (*n* = 9)**
Age	**68.8 (7.2)** 63.6 68.4 71.4	**66.6 (7.2)** 62.5 67.8 71.8	64.4 (7.3) 60.8 **63.2** 65.6
Gender *n* (%)			
Male	6 (27.3%)	3 (33.3%)	1 (11.1%)
Female	16 (72.7%)	6 (66.7%)	8 (88.9%)
Vertigo (VAS, 0 – 100)	37.6 (32.4) 4.25 **35.0** 69.5	0 (0) 0 0 0	21.1 (27.9) 0 **10.0** 25.0
Dizziness (VAS, 0 – 100)	33.9 (29.8) 10.0 **30.0** 50.0	0 (0) 0 0 0	24.1 (26.2) 10.0 **17.0** 25.0
Unsteadiness (VAS, 0 – 100)	29.3 (32.1) 0 **20.0** 57.5	0 (0) 0 0 0	23.1 (35.0) 0 **3.0** 25.0
VRBQ Total (% deficit)	18.0 (13.7) 8.4 **14.4** 26.2	6.1 (10.1) 0 **3.0**, 7.6	17.5 (19.1) 3.8 **12.2** 19.0
VRBQ QOL (% deficit)	15.6 (17.3) 3.0 **13.7** 22.8	11.5 (20.2) 0 **6.1** 12.2	21.3 (27.4), 0 **6.1** 30.4
VRBQ Anxiety (% deficit)	5.3 (9.8) 0 **0** 5.6	0.6 (1.9) 0 **0** 0	1.9 (5.6) 0 **0** 0
ABC (0 – 100%)	82.3 (13.1) 76.9, **83.1** 93.1	93.1 (9.5) 93.1 **95.6** 98.8	86.1 (19.4) 63.8 **98.0** 100.0
HAPAAS (0 – 94)	**62.7 (17.5)** 56.0 62.0 74.0	**68.8 (7.4)** 65.0 69.0 74.0	69.0 (14.5) 57.0 **71.0** 76.0
GAI (0 – 20)	3.6 (6.0) 0 **0** 4.0	1.7 (2.6) 0 **0** 2.0	2.4 (3.5) 0 **0** 3.0

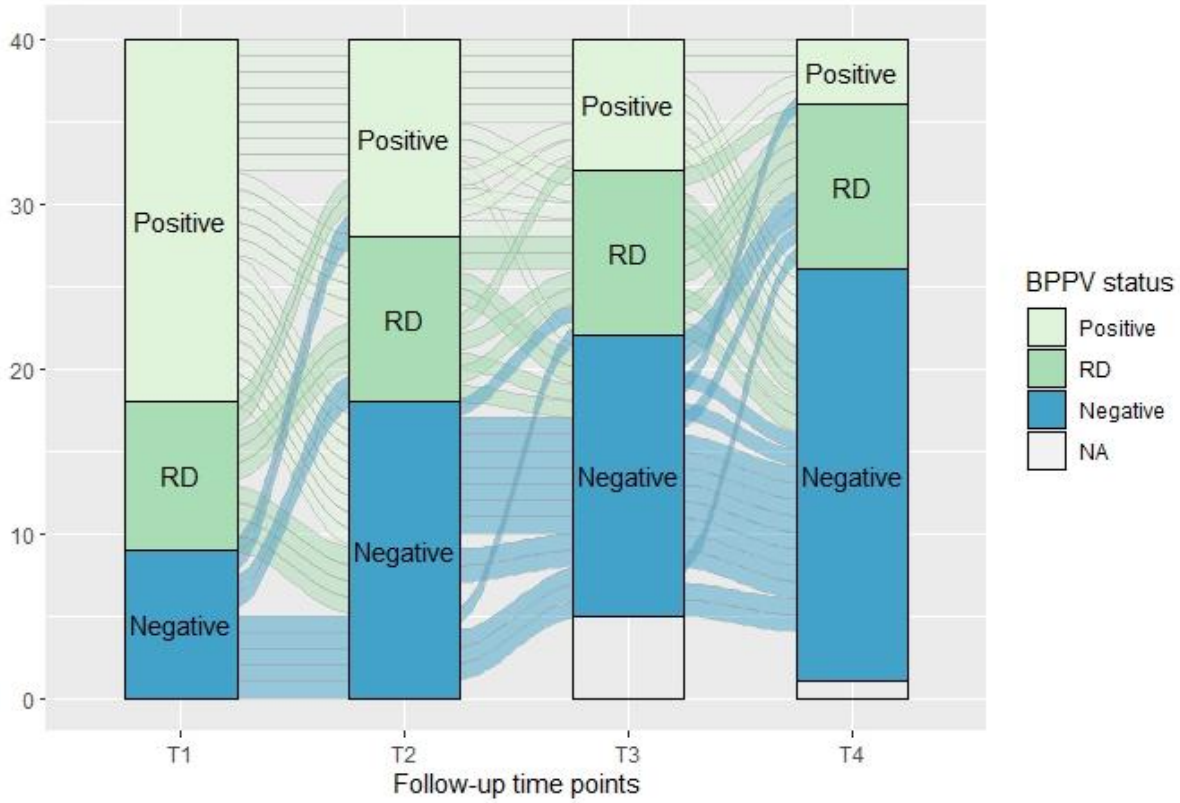
	Positive (*n* = 22)	Negative (*n* = 9)	Negative, but had residual dizziness (*n* = 9)
GDS-15 (0 – 15)	3.1 (3.5) 1.0 **1.0** 4.0	1.4 (1.2) 1.0 **1.0** 2.0	1.3 (1.4) 0 **1.0** 3.0
Comfortable walking speed with HHT (m/s)	**0.89 (0.22)** 0.79 0.88 1.04	**0.93 (0.23)** 0.85 0.97 1.00	**0.91 (0.15)** 0.86 0.91 0.96
Maximum/fast walking speed (m/s)	1.39 (0.28) 1.23 **1.45** 1.51	1.44 (0.37) 1.23 **1.67** 1.70	1.52 (0.21) 1.38 **1.55** 1.64
Left horizontal VOR Gain	**1.03 (0.18)** 0.93 0.98 1.17	**0.95 (0.12)** 0.92 0.96 1.02	**0.94 (0.05)** 0.92 0.94 0.97
Right horizontal VOR Gain	**1.08 (0.15)** 0.95 1.05 1.18	**1.01 (0.12)** 1.0 1.02 1.07	**1.05 (0.17)** 0.98 1.04 1.08
mCTSIB FIRMEO (time, sec)	30.0 (0) 30.0 30.0 30.0[a]	30.0 (0), 30.0, 30.0, 30.0[b]	30.0 (0) 30.0 30.0, 30.0[c]
mCTSIB FIRMEC (time, sec)	30.0 (0) 30.0 30.0 30.0[a]	30.0 (0) 30.0 30.0 30.0[b]	30.0 (0) 30.0 30.0 30.0[c]
mCTSIB FOAMEO (time, sec)	30.0 (0) 30.0 30.0 30.0[a]	30.0 (0) 30.0 30.0 30.0[b]	30.0 (0) 30.0 30.0 30.0[c]
mCTSIB FOAMEC (time, sec)	19.8 (11.9) 9.1 **29.3** 30.0[a]	23.8 (11.4) 22.9 **29.2** 30.0[b]	23.7 (10.9) 20.5 **30.0** 30.0[c]

Note. Continuous variables are summarized as mean (SD) and 25th 50th and 75th percentiles. Bold values denote the representative measures of central tendency for the specific variables.

[a]*n* = 11; [b]*n* = 4; [c]*n* = 7; VAS = Visual Analogue Scale; VRBQ = Vestibular Rehabilitation Benefits Questionnaire; QOL = Quality of Life; ABC = Activities-Specific Balance Confidence Scale; HAPAAS = Human Activity Profile Adjusted Activity Score; GAI = Geriatric Anxiety Inventory; GDS-15 = 15-Item Geriatric Depression Scale; HHT = horizontal head turns; VOR = Vestibulo-ocular Reflex; mCTSIB = modified Clinical Test of Sensory Integration on Balance; FIRMEO = standing on firm surface with eyes open; FIRMEC = standing on firm surface with eyes closed; FOAMEO = standing on foam with eyes open; FOAMEC = standing on foam with eyes closed.

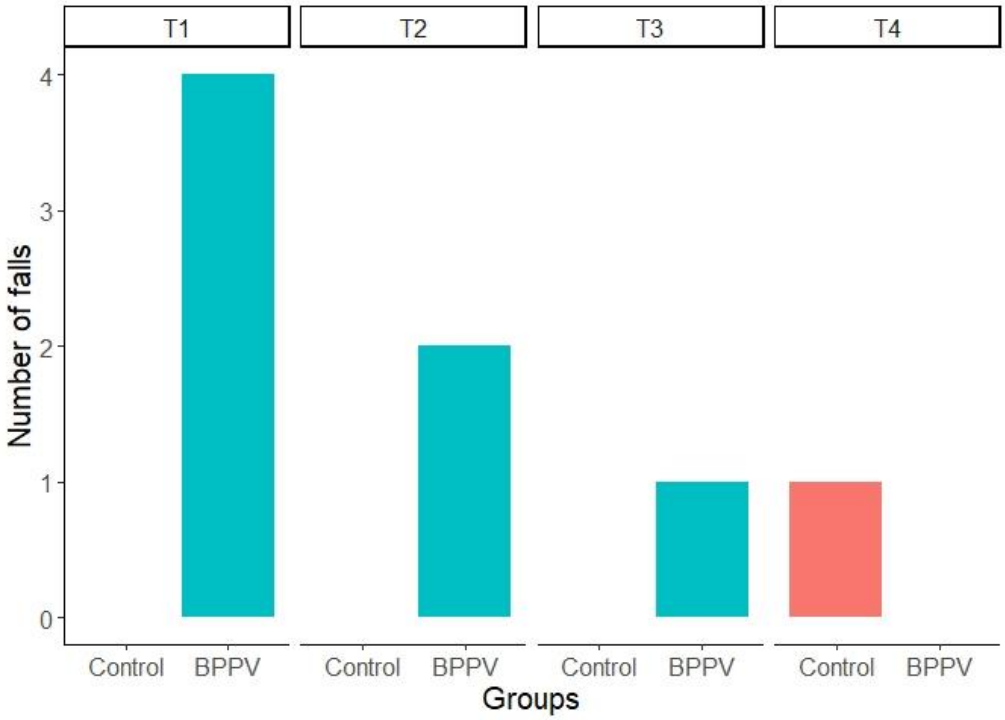
The number of falls in both BPPV and comparison control groups across all four assessment timepoints (over six months) are as presented in Figure 6.6. One observation was that there were more falls in the early time points. These timepoints correspond with the early treatment phase. The number of falls in the BPPV group fell with time to none in T4. The between-group difference, as analysed using negative binomial regression with previous history (number) of falls as covariate, yielded a regression coefficient of 1.22 (95% CI [-0.72, 4.22], p = .285). Exponentiating the regression results, the mean number of falls was 3.4 times (95% CI [0.5, 68]) higher in the BPPV group than in the comparison control group. This was an exploratory analysis. As the 95% confidence interval was wide (0.5 to 68) and the point estimate was clinically significant, it is plausible that the true between-group differences are clinically significant, despite the statistically insignificant results.

Figure 6.5 Diagram depicting the changes in BPPV status over 6 months



Note. Each horizontal (x-spline) segment is known as a flow, which represents a participant in this alluvial plot; Number of flows: 40; RD = residual dizziness; Missing cases at follow-ups represented by "NA".

Figure 6.6 Number of falls between BPPV and comparison control groups



6.6.3 Factors associated with residual dizziness at 6 months

For factors associated with residual dizziness and unsteadiness, the effect sizes for the continuous variables (except for age and VRBQ Anxiety subscale) were expressed as the adjusted difference between response estimates of the interquartile (75^{th} and 25^{th} percentiles) values of the independent variables. The duration of BPPV symptoms (from initial onset to initial treatment) was not significantly associated with VAS dizziness or unsteadiness. To further elaborate on the results, for example, the VAS dizziness score in participants with a symptom duration of 55 days was 0.10 (95% CI [-4.94, 4.74], p = .967) lower than those with a symptom duration of 12 days (other variables being equal) (see Table 6.4 and Figure 6.7).

Anxiety, as separately measured by the VRBQ Anxiety subscale and the Geriatric Anxiety Inventory (GAI), was found to be significantly associated with both dizziness and unsteadiness. As both 75^{th} and 25^{th} percentile scores for VRBQ Anxiety subscale were zero, VRBQ Anxiety scores of 0% and 10% were compared instead. Compared to participants with a VRBQ Anxiety score of 0%, those with a VRBQ Anxiety score of 10% scored 13.8 (95% CI [9.19, 18.30]) and 13.0 (95% CI [9.01, 16.90]) points higher in VAS dizziness and unsteadiness, respectively (both p

values < .001). Participants with a GAI score of 2 had a higher VAS dizziness score, by 4.08 (95% CI [2.16, 6.00]; p < .001) points, compared to those with a GAI score of 0. The difference for VAS unsteadiness was 4.02 (95% CI [2.09, 5.95], p < .001). The 15-item Geriatric Depression Scale (GDS-15) was also significantly associated with both dizziness and unsteadiness. Compared to participants with a GDS-15 score of 0, those with a GDS-15 score of 2 scored 6.30 (95% CI [2.39, 10.20], p = .002) and 7.45 (95% CI [3.92, 11.00], p < .001) points higher for VAS dizziness and unsteadiness, respectively.

The relationships between age and VAS dizziness, and unsteadiness were not linear (see Figure 6.8 for an example of relationship between VAS dizziness and age). Compared with participants aged 55 years old, those aged 67 years scored lower on the VAS dizziness and unsteadiness by 7.49 (95% CI [-25.30, 10.30]) and 8.30 (95% CI [-26.80, 10.20]) points (all p values > .05), respectively. Participants at 79 years old scored 25.0 (95% CI [8.73, 41.40], p = .004) points more on VAS dizziness than those at 67 years old. The difference for VAS unsteadiness was 29.1 (95% CI [12.40, 45.80], p = .001), with the older participants scoring higher on VAS unsteadiness than the younger counterparts. Age ≥ 67 years old was significantly associated with VAS dizziness and unsteadiness while age below 67 was not.

None of the following factors were significantly associated with VAS dizziness or unsteadiness in older adults with BPPV at six-months follow-up (p > .05): gender (male/female), history of BPPV, symptom duration, living arrangement (alone or with family/friends), and the number of comorbidities (see Table 6.4 and Figure 6.7).

Figure 6.7 Forest plot of adjusted estimate differences for various factors in association with residual dizziness and unsteadiness at 6 months

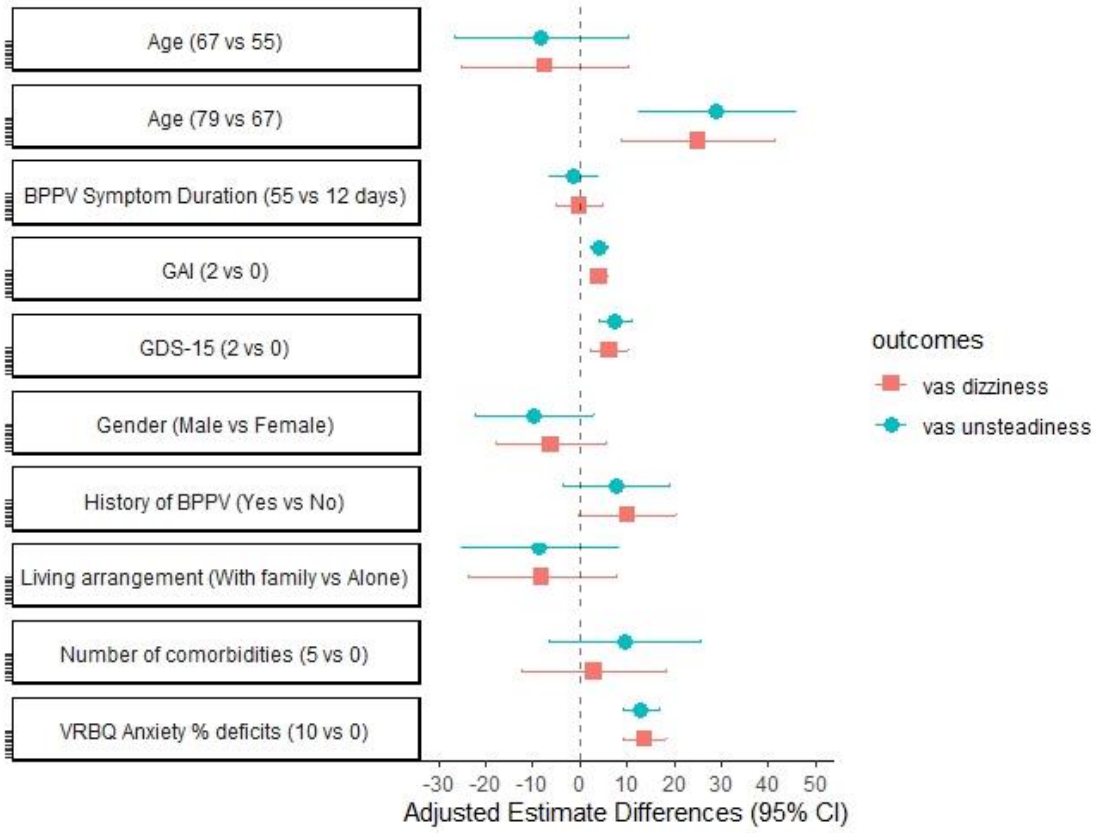
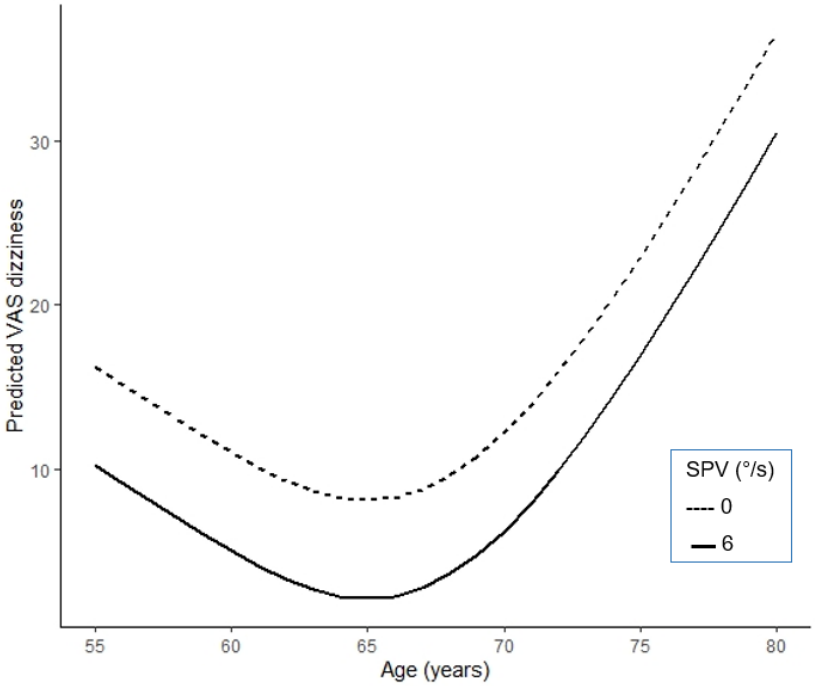


Figure 6.8 Effects of age on VAS dizziness based on regression model



Note. The predicted values of VAS dizziness against age. The slow phase velocity (SPV) values of 0 and 6 depict the BPPV status of being negative and positive, respectively.

Table 6.4 Factors associated with dizziness and unsteadiness in older adults who were treated for BPPV at 6 months

Factors	Comparison	VAS Dizziness			VAS Unsteadiness		
		Adjusted Difference	95% CI	*p* value	Adjusted Difference	95% CI	*p* value
Age (years)	67 vs. 55	-7.49	-25.30 to 10.30	.399	-8.30	-26.80 to 10.20	.370
	79 vs. 67	25.00	8.73 to 41.40	.004*	29.10	12.40 to 45.80	.001*
Gender	Male vs Female	-6.16	-18.00 to 5.67	.298	-9.68	-22.20 to 2.81	.120
Number of comorbidities	5 vs 0	2.93	-12.40 to 18.30	.700	9.45	-6.63 to 25.50	.241
History of BPPV	Yes vs. No	10.10	-0.33 to 20.60	.057	7.61	-3.65 to 18.90	.179
Duration of BPPV symptoms (days)	55 vs. 12[#]	-0.10	-4.94 to 4.74	.967	-1.38	-6.46 to 3.70	.585
VRBQ Anxiety (% deficit)	10 vs. 0^	13.8	9.19 to 18.30	< .001*	13.0	9.01 to 16.90	< .001*
GAI	2 vs. 0[#]	4.08	2.16 to 6.00	< .001*	4.02	2.09 to 5.95	< .001*
GDS-15	2 vs. 0[#]	6.30	2.39 to 10.20	.002*	7.45	3.92 to 11.00	< .001*
Living arrangement	Living with family/friends vs. Living alone	-8.11	-23.80 to 7.55	.300	-8.58	-25.10 to 7.92	.298

Note. Results shown are linear mixed models with VAS Dizziness and VAS Unsteadiness as dependent variables. All models were adjusted by age, gender, number of comorbidities (at baseline), slow phase velocity of positional nystagmus (BPPV status proxy) and time (actual number of weeks calculated from T1). Age was modelled using restricted cubic spline. [#]Interquartile range (IQR) of the factors; * = significant result; ^IQR for VRBQ Anxiety subscale was 0-0, hence could not be used to rescale the regression coefficient; VRBQ = Vestibular Rehabilitation Benefits Questionnaire; GAI = Geriatric Anxiety Inventory; GDS-15 = 15-Item Geriatric Depression Scale.

6.6.4 Physical performance and self-report measures associated with dizziness and unsteadiness at 6 months

As mentioned earlier, the coefficients were scaled to the interquartile range (IQR) of the continuous independent variable. The 25th and 75th percentile values for VAS dizziness were 0 and 20. For VAS unsteadiness, the values were 0 and 10, respectively. Overall, none of the three physical performance measures (maximum/fast walking speed, comfortable walking speed with horizontal head turns, and mCTSIB standing on foam with eyes closed) yielded significant associations with dizziness or unsteadiness at six months ($p > .05$) (see Table 6.5). Similar results were yielded for these outcomes in relation to VAS unsteadiness. Despite no significant associations being found, a closer look at the partial plots of the comfortable walking speed with horizontal head turns showed a possible relationship between the outcome and dizziness, but not so with unsteadiness, regardless of BPPV status (see Figures 6.9 and 6.10).

All self-report measures, except for the Human Activity Profile (HAP), were found to be significantly associated with residual dizziness at six months ($p < .05$) (see Table 6.5). Compared to participants with VAS dizziness and unsteadiness scores of zero, those with the higher VAS dizziness and unsteadiness scores had higher deficit scores for the Vestibular Rehabilitation Benefits Questionnaire (VRBQ) Total and Quality of life summary scores, and the Anxiety subscale (all p values < .001). Similarly, participants with higher VAS dizziness and unsteadiness scores were also found to have higher Geriatric Anxiety Inventory (p values < .05) and 15-item Geriatric Depression Scale scores (p values < .05), when compared to their counterparts with the lower VAS scores. For balance confidence, participants with the higher VAS dizziness and unsteadiness scores achieved lower scores on the Activities-specific Balance Confidence scale.

Figure 6.9 Partial plot of comfortable walking speed with horizontal head turns (HHT) associated with VAS dizziness at 6 months

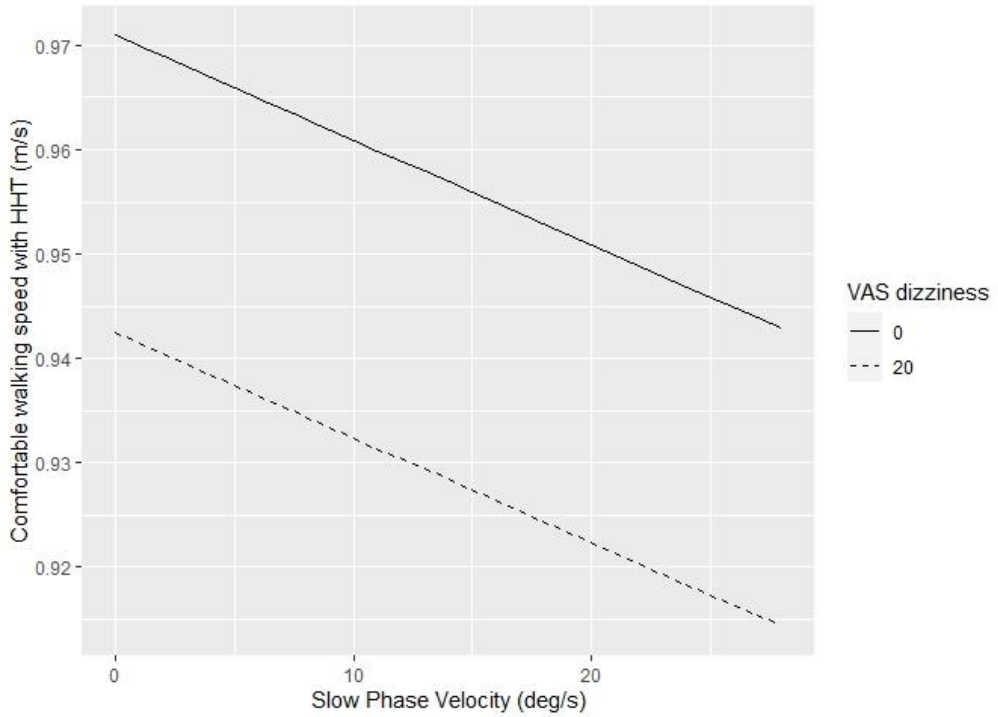


Figure 6.10 Partial plot of comfortable walking speed with horizontal head turns associated with VAS unsteadiness at 6 months

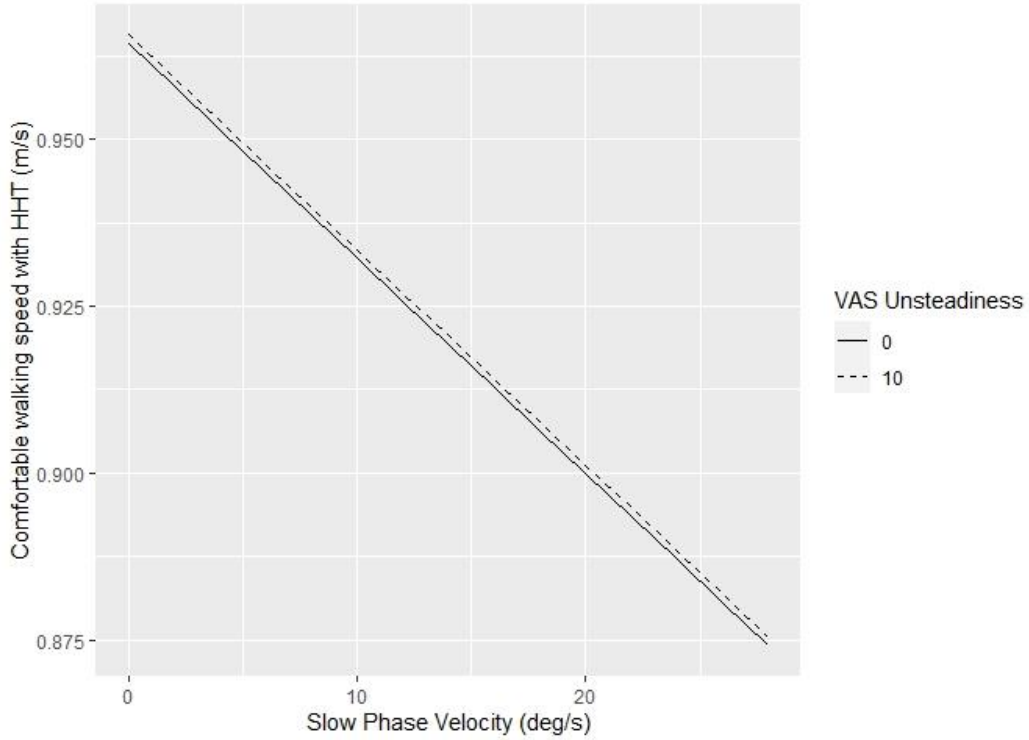


Table 6.5 Association of dizziness and unsteadiness with physical performance and self-report measures in older adults who were treated for BPPV at 6 months

Dependent Variables	IV: VAS Dizziness (20 vs. 0)[#]			IV: VAS Unsteadiness (10 vs. 0)[#]		
	Adjusted Difference	95% CI	*p* value	Adjusted Difference	95% CI	*p* value
Maximum/fast walking speed (m/s)	0.009	-0.024 to 0.041	.605	0.006	-0.011 to 0.023	.501
Comfortable walking speed with HHT (m/s)	-0.023	-0.051 to 0.005	.101	-0.001	-0.016 to 0.013	.855
mCTSIB FOAMEC (sec)	-0.05	-1.95 to 1.85	.961	0.28	-0.62 to 1.18	.539
VRBQ Total (% deficit)	6.49	5.01 to 7.96	< .001*	3.76	2.98 to 4.55	< .001*
VRBQ QOL (% deficit)	5.48	3.57 to 7.39	< .001*	3.49	2.44 to 4.53	< .001*
VRBQ Anxiety (% deficit)	2.94	1.98 to 3.91	< .001*	1.52	1.02 to 2.02	< .001*
Geriatric Anxiety Inventory	0.78	0.15 to 1.42	.016*	0.61	0.27 to 0.96	< .001*
The 15-item Geriatric Depression Scale	0.38	0.06 to 0.70	.020*	0.27	0.09 to 0.45	.004*
The Activities-specific Balance Confidence Scale	-4.98	-6.49 to -3.48	< .001*	-2.82	-3.71 to -1.93	< .001*
HAP Adjusted Activity Score	-0.64	-2.40 to 1.13	.478	-0.01	-1.02 to 0.99	.977

Note. Results shown are linear mixed models with the physical performance and self-report outcomes as dependent variables, and VAS Dizziness and VAS Unsteadiness as independent variables. All models were adjusted by age, gender, number of comorbidities (at baseline), slow phase velocity of positional nystagmus (BPPV status proxy) and time (actual number of weeks calculated from T1). [#] = 75th and 25th percentile values; * = significant result; IV = independent variable; HHT = Horizontal Head Turn; mCTSIB = modified Clinical Test of Sensory Integration on Balance; FOAMEC = standing on foam with eyes closed; VRBQ = Vestibular Rehabilitation Benefits Questionnaire; HAP = Human Activity Profile.

6.7 Discussion

Benign Paroxysmal Positional Vertigo is one of the most common causes of dizziness with increased prevalence in the older adult group. Repositioning manoeuvres are proven to be efficacious in ameliorating symptoms and resolving BPPV in a high proportion of patients. However, some patients reported symptoms of residual dizziness despite BPPV resolution. To date there has been limited evidence about residual dizziness in older adults with BPPV, including its associated factors and impact on physical performance, mental health, and other self-report measures. This longitudinal study on older adults with BPPV aimed to address the above concerns and explore its implications for current BPPV management.

In this study, up to 60% of the older adult participants reported residual dizziness symptoms. At the various time points of reassessment over the six months following initial repositioning manoeuvres, the percentage of participants who had residual dizziness amongst those who tested negative for BPPV ranged from 30% to 50%. The findings here are similar to the prevalence rates of 30% to 67% for residual dizziness reported by other studies which, except for one study (Teggi et al., 2011), included adult participants of all ages (Dispenza, Mazzucco, Mazzola, & Martines, 2019; Duan et al., 2018; Martellucci et al., 2016; Seok et al., 2008; Teggi et al., 2013; Tirelli, Nicastro, Gatto, & Tofanelli, 2017).

A systematic review (Sim et al., 2019) (see Chapter 3) found that there is a paucity of studies on residual dizziness in older adults with BPPV. Most studies included adults of different ages and hence, it was not possible to perform a meta-analysis on the selected studies. The current study, with a focus on older adults with BPPV, aims to contribute to the evidence in this area. In this study, several factors such as age ≥ 67 years old, anxiety (quantified by the VRBQ Anxiety subscale and the Geriatric Anxiety Inventory separately) and depression (quantified by the 15-Item Geriatric Depression Scale) were found to be significantly associated with residual dizziness. Other factors such as age below 67 years old, duration of BPPV symptoms (BPPV symptom onset to initial treatment), previous history of BPPV, and living arrangements were not significantly associated with residual dizziness.

The finding that residual dizziness is linked to advanced age is in agreement with previous studies (Martellucci et al., 2016; Teggi et al., 2011), including more recent studies (Dispenza et al., 2019; Vaduva et al., 2018). Previous studies also found that the duration of vertigo (Faralli et al., 2016; Seok et al., 2008; Teggi et al.,

2011; Teggi et al., 2013) and previous history of BPPV (Dispenza et al., 2019) were associated with residual dizziness. Both were not significant factors of residual dizziness in this study, although history of BPPV was near significance (p = .057) in association with the VAS dizziness score. Dispenza et al (2019) postulated that recurrence and residual dizziness were more prevalent in subjects above 65 years old, thus the associations between recurrence and history of BPPV with residual dizziness. This present study did not investigate the association between residual dizziness and recurrence. However, it is notable that residual dizziness was reported in five out of six participants who had BPPV recurrences. Interestingly, the same study also reported that subclinical BPPV could be a risk factor for residual dizzinesss (Dispenza et al., 2019). Thirty-six participants, who exhibited no nystagmus during positional tests, were treated again with repositioning manoeuvres which resulted in resolution of the residual symptom. Another recent study found that older age, positive calorie tests, and poor bone mineral density were independently associated with residual dizziness in participants who were successfully treated for posterior canal BPPV (Jiang et al., 2020).

Mental health problems, such as depression and especially anxiety, have been shown to be highly associated with residual dizziness (Faralli et al., 2009; Martellucci et al., 2016; Teggi et al., 2011; Vaduva et al., 2018; Wei, Sayyid, Ma, Wang, & Dong, 2018). The findings of this study concur with those of earlier studies. Dizziness problems may bring upon or exacerbate anxiety symptoms or minor phobias while anxiety may exacerbate or induce dizziness problems (Staab & Ruckenstein, 2003). Older adults with BPPV should be screened for residual dizziness when cleared of BPPV. They should also be screened or monitored for possible anxiety and depression symptoms, especially in those with residual dizziness or history of dizziness problems.

Apart from higher depression and anxiety scores, fear of falling was also more prevalent in older adults with dizziness (47%) compared to those without dizziness (3%) (Burker et al., 1995). According to Yardley (2004), fear of falling could be viewed as a specific form of anxiety towards falling. Fear of falling can lead to activity restrictions, changes in posture and gait, functional decline, and falls (Choi et al., 2017; Deshpande et al., 2008; Yardley, 2004). A study found that older adults, compared with younger adults, were less accurate in identifying anxiety and depression symptoms (Wetherell et al., 2009). However, older adults were better at

identifying depression symptoms than anxiety ones. Hence there is the need to include proper screening of anxiety and depression in the management of older adults with BPPV, instead of relying mainly on their subjective accounts.

This study also explored the relationship of residual dizziness with the physical and self-report measures of older adults with BPPV at six months. Generally, there were no significant associations between residual dizziness and the physical measures (fast walking speed, comfortable walking speed with horizontal head turns, and the modified Clinical Test of Sensory Integration on Balance) and the Human Activity Profile (self-report level of physical activities). However, the other self-report measures such as the Activities-specific Balance Confidence, the Vestibular Rehabilitation Benefits Questionnaire (Total, Quality of life and Anxiety), the Geriatric Anxiety Inventory and the 15-Item Geriatric Depression Scale, were all significantly associated with residual dizziness. The regression models were all adjusted for age, gender, number of comorbidities (at baseline), the slow phase velocity of positional nystagmus (BPPV status quantified using a continuous measure obtained during positional tests), and time (number of weeks from T1).

From the above findings, residual dizziness was associated with the self-perceived levels of handicap and quality of life, as well as the mental health of this group of older adults with BPPV at six months. The older adult participants in this study were generally well-functioning individuals in that most were working, and some were caregivers to spouse or grandchildren. The interquartile (25^{th} and 75^{th} percentile) values of the VAS dizziness and unsteadiness scores for this group of older adults were 0 and 20, and 0 and 10, respectively, on a 100 point scale. The low intensity levels of dizziness and unsteadiness experienced by most of the participants might explain why walking speeds, balance, and physical activity levels were not associated with residual dizziness and unsteadiness.

Persons with vestibular problems, such as vertigo, dizziness, and disequilibrium, have substantially greater handicap and decreased quality of life, with increased gait and balance dysfunction, compared to those without such symptoms. However, studies have found that these subjective symptoms do not always align with physical or functional dysfunction (Kammerlind, Ledin, Skargren, & Odkvist, 2005; Meli, Zimatore, Badaracco, De Angelis, & Tufarelli, 2006; Morimoto et al., 2019). Two studies on adults with chronic dizziness reported that there were no significant correlations between objective (physical activity, postural stability, gait,

and vestibular function) and subjective (balance confidence, handicap, anxiety, quality of life) measures (Meli et al., 2006; Morimoto et al., 2019). Kammerlind et al (2005) followed up on subjects who had Vestibular Neuronitis for three to six years. They found that while depression, anxiety, and health-related quality of life measures differed significantly between subjects with and without remaining symptoms, they did not differ in the physical outcomes such as balance and vestibular function tests. These findings confirm the relationship between the subjective experience of dizziness, perceived handicap, and psycho-emotions such as anxiety and depression, as discussed earlier. With residual dizziness and increased levels of mental health issues, older adults with BPPV may restrict their physical and functional activities, despite being physically capable of sustaining these activities. This may lead to deconditioning and further weakens the vestibular system and may lead to undesirable consequences such as falls. This reinforces the need to screen older adults with BPPV for possible mental health issues as part of the management.

This longitudinal study followed a group of 40 older adults with BPPV, who had undergone initial repositioning manoeuvres (≤ three treatment sessions), for six months. At the start (T1), more than half of this older adult group still tested positive for BPPV despite initial treatment. At T2, one month from T1, 28 participants tested negative for BPPV. Overall, only about a third of the group had early resolution of BPPV and remained symptom-free throughout the study duration. The findings in this study run contrary to studies that found the success rates of initial repositioning manoeuvres to be over 90% in older adults with BPPV (Kasse et al., 2012; Salvinelli et al., 2004; Vaz et al., 2013) and that age does not affect efficacy of repositioning manoeuvres (Monobe, 2001; Wei et al., 2018). However, Korres et al (2006), in investigating the prognosis of subjects with BPPV treated with repositioning manoeuvres, found that younger subjects had significantly better outcomes than older subjects at initial treatment but not for repeated treatment outcome. One study also reported that age older than 50 years old was a potential risk factor for treatment failure for subjects with BPPV (Babac et al., 2014), while another two studies found most subjects who remained positive, post initial repositioning manoeuvres, were above 70 years old (Batuecas-Caletrio et al., 2013; Prokopakis et al., 2013).

Other possible factors affecting initial BPPV treatment success reported by various studies included head trauma (Babac et al., 2014; Del Rio & Arriaga, 2004;

Prokopakis et al., 2013; Sato et al., 2013), secondary BPPV (Babac et al., 2014; Korres et al., 2006; Monobe, 2001), history of or co-existing vestibular pathology (Del Rio & Arriaga, 2004; Prokopakis et al., 2013), and the presence of anxiety or depression (Honaker et al., 2013; Wei et al., 2018). Traumatic BPPV secondary to head injury was excluded from this study apriori. While two participants had a history of labrynthitis, one with vestibular migraine, two had osteoporosis/osteopenia and three had hearing loss issues, none of the BPPV diagnoses were clearly linked to these medical conditions. It was also difficult to determine the history of vestibular pathology for some participants who had complained of previous episodes of dizziness which were not properly examined and diagnosed. The two participants with persistent BPPV throughout this study had no prior diagnosis of other vestibular problems except for BPPV. Further vestibular tests were later ordered by the ENT doctor for one of these participants. However, that was declined by the participant. Despite still experiencing BPPV symptoms at the end of the study period, one of them expressed, during the in-depth interview (Chapter 7), that she had improved considerably with the ongoing physiotherapy and was able to function better compared to before treatment.

Six out of 40 (15%) older adult participants (mean age 67.3 (*SD* = 7.27) years) encountered BPPV recurrence in this study. A similar recurrence rate of 13.5% within six months was reported by a large retrospective study of 259 subjects with an average age of 58.6 years (range, 20 – 93 years) (Macias, Lambert, Massingale, Ellensohn, & Fritz, 2000). In another study, three out of 14 older adult subjects (21.4%) experienced recurrence over a 13-week duration (Ribeiro et al., 2016). In comparison, their subjects were older (≥ 65 years old) and had chronic BPPV (≥ six months duration without treatment). Batuecas-Caletrio et al (2013) reported that the BPPV recurrence rate was significantly higher in their older adult group (mean age 77.7 years; *SD* not provided) at 23.7%, compared with 15.5% in the adult group (mean age 53.8 years) over a two-year period. Kao et al (2009) reported that BPPV recurrence in subjects aged 65 years and above was 1.7 times higher than those younger than 65 years old. Several other studies have also reported increased prevalence of BPPV recurrence in older adults (Korres et al., 2006; Prokopakis et al., 2013). Conversely there were studies that concluded age was not a determining factor in BPPV recurrence (Del Rio & Arriaga, 2004; Pérez et al., 2012; Yeo et al., 2018; Zhu et al., 2019).

The studies cited varied in methodology with most being retrospective studies. The follow-up duration also differed widely, although recurrence rates were shown to increase with time (Bhattacharyya et al., 2017). The studies also differed in ways of determining recurrence. While some studies had required their subjects to be re-examined using positional tests, some studies had used phone surveys and hence recurrence was based on the subjective symptoms reported. Determining BPPV recurrence mainly by reported symptoms, without confirmatory physical examinations, might lead to inaccurate recurrence rates. However, long term studies require greater participant commitment and compliance, as well as research funding, all of which can be difficult to obtain. Another way of obtaining such data may be the establishment of a clinical registry on BPPV, and the collaboration between different clinical units or institutions.

In this six-month long study, the number of falls between the BPPV and comparison control groups was not significantly different after adjustment for previous history (number) of falls. In total, the comparison control group had one faller (5%) who sustained one fall. The BPPV group had five fallers (12.5%) and a total of 7 falls. Four participants each had a single fall, and the causes were trips and loss of balance. One participant had a total of three falls, and she was the oldest at 80 years old. All her falls were due to BPPV-related vertigo attacks. This highlights a potential increased risk of falls and actual falls faced by older adults with BPPV. There is the need for close falls monitoring and falls prevention measures in this population, particularly in the early treatment phase which appeared to be when most falls occurred in the present study. These older adults should also be screened and managed for other (non-BPPV related) falls risk factors. It is also integral to include proper patient and caregiver education on the importance of falls monitoring and prevention measures.

Limitations

This study had several limitations. The sample size was small at 40. The target sample size was 108. The small sample size lowers the statistical power and affects the reliability and validity of the study. It would have been ideal to control for the prescription of vestibular and balance exercises in the analysis of association with residual dizziness. However, due to the small sample size, more pertinent confounders were included instead. The duration of residual dizziness could have

been included in the assessment to provide a better understanding of features of residual dizziness.

The recurrence rate might have been under-estimated in this study, as there were several participants who reported recurrence of symptoms in between the planned follow-ups but had refused to return for further assessment and treatment. These symptoms eventually resolved spontaneously before the subsequent assessment timepoint. Some assessment results could not be used for analyses. The comfortable walking speed and the Sensory Organisation Test results were only available for the first 15 participants because of changes to the protocol to improve study recruitment; hence they were also not included in the analyses. However, similar measures involving less measurement equipment and/or time were introduced; and used successfully in subsequent participants and in the analyses. The electronic VAS (for rating dizziness, vertigo, and unsteadiness) and the Chinese translation of VRBQ were not validated in this patient population and this might affect the credibility of the results. The findings of the study are based on the data collected from a group of functionally independent older adults. Therefore, the results may not be generalisable to other older adult populations such as those with frailty or decreased physical capacities, or those who are institutionalized.

6.8 Conclusion

The initial effectiveness of the repositioning manoeuvres in older adults with BPPV in this study was only 45%, and lower than reported in other studies. The BPPV recurrence rate was 15%. Up to 60% of the older adults with BPPV experienced residual dizziness. Age, anxiety, and depression measures were associated with residual dizziness while gender, living arrangements, history of BPPV, and the duration of BPPV symptoms were not. The current study results showed that self-report handicap, quality of life, balance confidence, and mental health outcomes were associated with residual dizziness. Physical performance measures and physical activity level were not associated with residual dizziness.

The study findings suggest that older adults with BPPV may benefit from a holistic assessment that incorporates these non-vestibular domains, such as anxiety and other negative emotions, as well as falls risk and actual falls. In addition to the standard treatment of repositioning approaches for management of BPPV, early

intervention could also be provided to target these identified non-vestibular impairments, in an attempt to improve longer term outcomes.

The research reported in this chapter was partially supported by the SGH Research Grant - New Investigator Grant (SRG - NIG) (Grant number: SRG-NIG #10/2017; awarded to Dr Dawn Tan, Co-supervisor, and Principal Investigator (SGH).

Chapter 7 A Qualitative Study Exploring the Experiences of Older Adults with Benign Paroxysmal Positional Vertigo

7.1 Abstract

Older adults are susceptible to dizziness, and BPPV is the most common cause of peripheral dizziness in this patient population. Much remains unknown about the impact of BPPV and its management on older adults, and their feelings and perceptions. The aim of this study was to explore the personal experiences of older adults with BPPV. The qualitative method used was the in-depth interview which was conducted at one month after the first follow-up (T2). All older adult participants from the BPPV group (from the earlier cross-sectional studies) were invited to join. The semi-structured interviews were conducted using open-ended guiding questions. All interviews were audio-recorded and transcribed. The data analysis used was thematic analysis. Two research team members worked independently to generate the codes and themes before coming together to review, and further refine and name the themes. A total of 13 interviews were conducted. Four main themes were identified: (i) physical and functional impacts; (ii) psycho-emotional and social impacts; (iii) treatment and recovery; and (iv) BPPV literacy. These findings indicated the negative physical and psycho-emotional impacts of BPPV on these participants. They reported improvement in symptoms and function with treatment; but also highlighted areas with less optimal improvements, and the need for both patient- and public- education on BPPV.

7.2 Introduction

In the previous two chapters, the cross-sectional and longitudinal quantitative studies explored both short- and long-term treatment effectiveness of BPPV treatment, physical and self-report measure performances, and factors associated with residual dizziness in older adults with BPPV. In this chapter, the qualitative study exploring the lived experiences and perceptions of older adults with BPPV is presented.

Benign Paroxysmal Positional Vertigo (BPPV) causes transient symptoms of vertigo with head positional changes, unsteadiness, and light-headedness (Parnes et al., 2003). It is one of the most common causes of dizziness amongst older people

(Hansson, Mansson, & Hakansson, 2005; Lena Kollén et al., 2012; van Leeuwen & Bruintjes, 2014). Although BPPV can affect people of all ages, it is more prevalent in older people (von Brevern et al., 2007). Along with the vertiginous attacks, some may experience gait and balance issues with an increased risk of falls (Chang et al., 2006; Da Silva, De Figueiredo Ribeiro, De Medeiros Freitas, De Britho Macedo Ferreira, & Guerra, 2016; Oghalai et al., 2000; Oliva Domínguez et al., 2005), as well as anxiety (Pollak et al., 2003). Repositioning manoeuvres have been reported to resolve BPPV, ameliorate symptoms and improve physical functions (Chang et al., 2008; Kao et al., 2009; Kasse et al., 2012; Pollak et al., 2003). However, despite the positive results, there exists some evidence on the persistence of negative emotions (Pollak et al., 2012), balance problems (Da Silva et al., 2016; Di Girolamo et al., 1998), and residual dizziness (Teggi et al., 2011; Teggi et al., 2013), including some reported in the Chapters 3, 5 and 6 of this thesis.

Dizziness is a symptom frequently reported amongst the older adult population (de Moraes, Soares, Ferriolli, & Perracini, 2013), and BPPV is only one, although a common cause of it. Dizziness has been shown to be associated with frequent falls, fatigue, drowsiness, and decreased self-perceived participation and autonomy in older people (de Moraes et al., 2013; Mueller et al., 2014). A qualitative study of older adults with chronic dizziness (Olsson Moller et al., 2014) found that this group of older adults grappled with having control over their symptoms and their lives. They also mentioned the lack of support and understanding from both social support and health care institutions (despite frequent health care contacts). This study provided patient perspectives about their struggles: trying to get a cure, seeking normality in living, facing restrictions in life and potential threats, and the lack of support both socially and from healthcare institutions. While quantitative studies on older adults with dizziness may provide objective data on their symptoms and physical functions, qualitative studies such as this allow important insights into the patients' world, to know and understand their experiences and thoughts. Results from these qualitative studies may help to inform improved clinical interventions and outcomes for patients.

Benign Paroxysmal Positional Vertigo has some unique characteristics relating to the associated dizziness and symptoms, and management approaches that differentiate it from other forms and causes of dizziness. For example, BPPV can be acute and has potential for quick resolution (either spontaneous or after

repositioning manoeuvres) (T. D. Fife et al., 2008). It is also a recurrent condition which can result in potential adverse circumstances such as recurrent vertigo attacks, activity restriction, anxiety, and falls (Gananca et al., 2010; Pollak et al., 2003; Pollak et al., 2012). Benign Paroxysmal Positional Vertigo may also become chronic (Bhattacharyya et al., 2017). Because of these differences, older adults with BPPV may or may not have similar concerns as their counterparts with other forms of dizziness. It is also valuable to consider the perspectives of BPPV patients who may experience different treatment outcomes. Some patients may have good resolution, some may have ongoing symptoms, and others may have had resolution and then a recurrence (compared to the study by Olsson and colleagues (2014) which studied subjects with chronic dizziness). It would be beneficial for healthcare professionals to gain knowledge and insight into how older adults feel about BPPV and the impact on their lives. This will help to understand the limitations of current BPPV management from the patients' perspectives and may help inform changes to improve the care for this population. Moreover, BPPV is often perceived as a benign and an easy condition to treat, and once treated, everything returns to normal for the person. An important question that warrants clarification is "Does BPPV have little impact on a person's life because it is benign and easily treated?". At the time of commencing this study, based on a literature search, there have been no previous published qualitative studies exploring perspectives of older people with BPPV.

7.3 Objectives

To explore the experiences of older adults on how BPPV and its management affected them.

7.4 Methods

7.4.1 Design

This qualitative study was conducted using semi-structured in-depth interviews with the participants from the BPPV group reported in the Cross-sectional studies 1 and 2 (Chapter 5), and the Longitudinal study (Chapter 6). Ethical approvals for this qualitative study were obtained from both SingHealth (Singapore, CIRB reference 2016/2799) and Curtin University (Australia, HRE 2017-0008) Institutional Review Boards (see Appendices J and K).

7.4.2 Participants

All participants from the BPPV group reported in the Cross-sectional studies 1 (time point T0) and 2 (time point T1) were invited to participate in the interview during recruitment. Apart from repositioning manoeuvres, some participants were also taught the Brandt-Daroff exercise for them to perform at home. For other problems identified by their physiotherapists, the participants were also prescribed balance exercises and vestibular exercises such as the gaze stabilisation and habituation exercises. As the studies in this thesis were mainly observational, all participants underwent the usual medical and physiotherapy care as provided at the Singapore General Hospital (Singapore). Sampling for this qualitative study was aimed to be up to the point of data saturation.

7.4.3 Procedure

The participants were informed that the interviews would take place one month after the first follow-up (T1) (refer to Figure 4.1 regarding the different follow-up occasions and timing). It was also made known to the participants that the interviews would be recorded with an audio recorder to enable the data to be transcribed later. The participants indicated their consent (or not) to the interview and audio-recording in the Ethics-approved Patient Information Consent Form (PICF) (see Appendix M). The in-depth interview was conducted in a semi-structured form, with guided open-ended questions at hand for the interviewer (the open-ended questions are reported in Appendix N). The interview explored experiences of the participants on 1) how BPPV had impacted on the various aspects of their lives; 2) their understanding of “BPPV” and expectations of management; 3) perceptions of how the management of BPPV had affected them; 4) if the management met their expectations; and 5) how they felt as a patient/person being part of the recovery process and interactions with healthcare workers.

The interviews were conducted in a private consultation room at the Physiotherapy Outpatient Clinic in SGH by the researcher (PhD candidate). The interviews were conducted mostly in English, with Mandarin (some parts that needed translation) being used for some participants. The duration of the interviews ranged from 15 minutes to slightly over an hour. To maintain confidentiality, each interview was labelled using the participant code (as assigned in the Cross-sectional and Longitudinal studies).

7.4.4 Data analysis

Data analysis was conducted using the thematic analysis (Braun & Clarke, 2006) as outlined in Chapter 4 (Section 4.7.2). All recorded data were transcribed verbatim. The transcripts were pass-word protected and only accessible to the study team. All transcripts were proof-read by another team member. Any mistakes or discrepancies in the transcriptions were discussed and corrected. The transcripts were canvassed for generating the initial codes, followed by themes. The generation of codes and themes were undertaken by two independent researchers (EL and ES – PhD Student) in the study team. After reviewing the themes (main- and sub-) individually, they came together to further review, refine, and name the themes, including reorganising the codes and data extracts. Disagreements regarding thecodes, themes, and data extracts were resolved through multiple discussions between EL and ES. The emerging themes were also discussed and finalised with one supervisor (KH).

7.5 Results

Nineteen participants from the BPPV group consented for the interviews but six were unable to attend the session due to various unforeseen circumstances (work, home, and medical reasons). A total of 13 participants took part in the interviews (see Table 7.1). The participants were between 55 and 79 years old (*M* = 64.7, *SD* = 6.3). Four (30.8%) were men. Most of the participants (69.2%) were married and two participants (15.4%) were single. A little over half of the participants (53.8%) were still working and 84.6% were living with their families. Ten of the participants (76.9%) reported a prior history of BPPV. At the time of the interviews, five participants (38.5%) had BPPV symptoms, including two who reported recurrence of symptoms just days before the interview (Follow-up 2, T2).

Table 7.1 Participant demographics and BPPV status

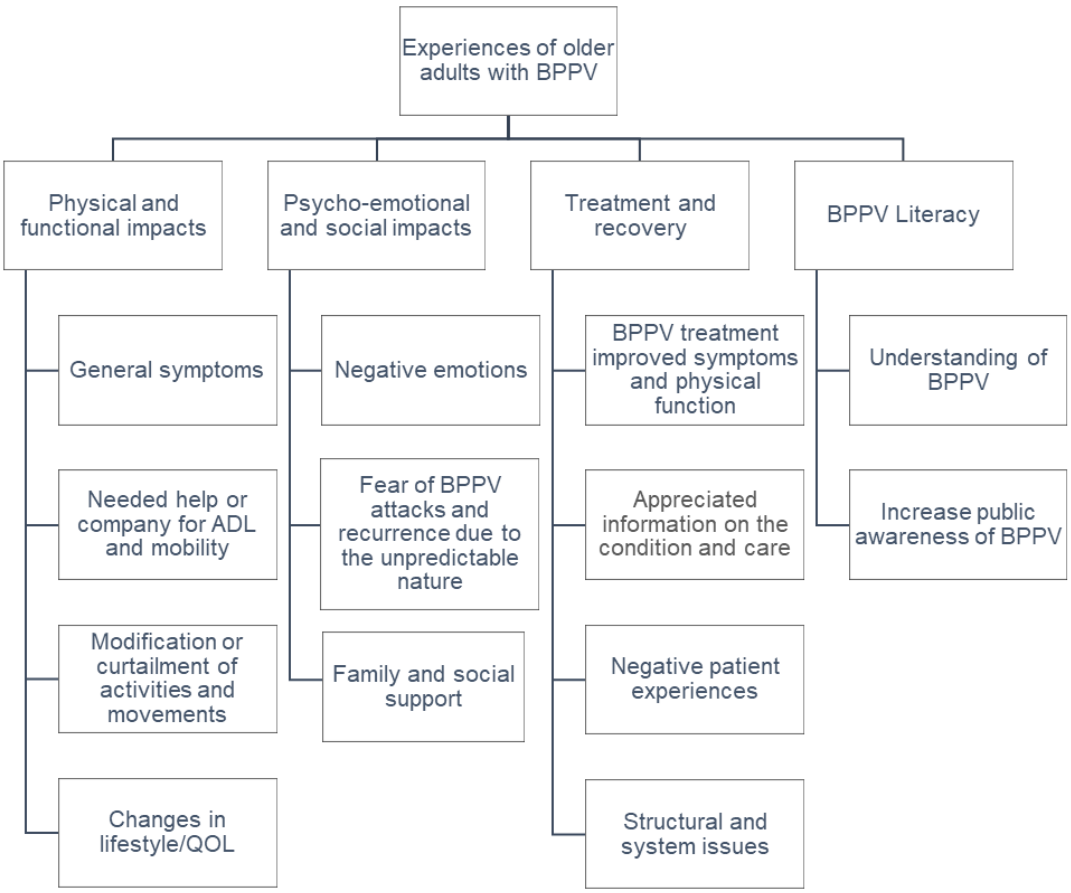
Participant	Age (years)	Gender	Marital status	Work	Living situation	Prior history of BPPV	BPPV diagnosis as at time of interview[#]
P01	71.5	F	Divorced	Retired/Not working	Alone	Yes	Nil BPPV
P02	60.8	F	Widowed	Still working	With family	No	Nil BPPV
P03	55.3	M	Married	Still working	With family	Yes	Left Horizontal Canalithiasis*
P04	78.9	M	Married	Retired/Not working	With family	Yes	Nil BPPV
P05	62.5	F	Married	Still working	With family	Yes	Nil BPPV
P06	59.6	F	Married	Still working	With family	Yes	Nil BPPV
P07	67.8	F	Married	Retired/Not working	With family	Yes	Right Posterior Canalithiasis
P08	68.7	M	Single	Retired/Not working	With family	Yes	Bilateral Posterior Canalithiasis
P09	63.7	M	Single	Retired/Not working	Alone	Yes	Left Horizontal Cupulolithiasis
P10	66.2	F	Married	Still working	With family	No	Nil BPPV
P11	65.6	F	Married	Retired/Not working	With family	No	Right Posterior Canalithiasis*
P12	56.9	F	Married	Still working	With family	Yes	Nil BPPV
P13	63.1	F	Married	Still working	With family	Yes	Nil BPPV

Note. [#]BPPV diagnosis confirmed with positional tests; *Recurrence after testing negative at T1; F = female; M = male; BPPV = benign paroxysmal positional vertigo.

Interviews occurred on average five weeks after participant's initial assessment and treatment session at the Singapore General Hospital. Four main themes with several sub-themes emanated from the interview data (see Figure 7.1). While the themes resonated throughout all the interviews, variations in personal experience and level of impact were also evident. Quotes from the interview are presented with the results. Some punctuation marks are used in the quotes such as the ellipses in parentheses (indicate deletion of irrelevant words or sentences) and the brackets (addition of words by researchers to provide clarity).

The data were obtained through interviews with 13 participants who had given consent to taking part in this qualitative study. Generally, data obtained from the last several interviews broadly uncovered themes and sub-themes comparable to the earlier interviews.

Figure 7.1 Diagram of main themes and sub-themes generated from the interview data



Note. ADL = activities of daily living; QOL = quality of life; BPPV = benign paroxysmal positional vertigo

7.5.1 Physical and functional impacts

7.5.1.1 General symptoms

Dizziness or vertigo, nausea and vomiting, feeling unsteady, and problems with balance and walking were common symptoms highlighted by the participants. Some participants experienced several symptoms while a couple of participants reported having few symptoms. Severity of symptoms also varied from participant to participant.

"I was unable to move well at all. I had slight dizziness whenever I lie down, got up from bed or moved my head… (…) …When I was walking, I felt like I am swaying." (P02)

"Yes, it was spinning, and I sat on the bed and screamed for my husband… (…) … but it kept spinning. I tried to sit up. Couldn't sit up. Kept falling over. Couldn't sit or do anything" (P07)

"It doesn't affect me very much in my normal life… (…) … for my case, is just confined to going to bed at night before I sleep, that is resting the back of my head onto the pillow. That very moment it lasted only a few split seconds I get the giddiness." (P04)

Dizziness, vertigo, and balance issues increase the risk of falling and can often directly cause falls. One participant (P06) expressed a fear of falling due to sudden unpredictable vertigo attacks. Other participants described situations where they felt they were at risk of falling or an actual fall happened:

"The first few times in November when I was feeling this, I just had to grab something just to feel steady. I was just fearful I would fall over due to this unsteady feeling." (P09)

"Yes, a few times. I felt giddy, then I couldn't hold anything to support myself, then I fell on the floor." (P13)

Vertigo is a key symptom of BPPV and often a major concern to the participants. It is classically described as a "spinning" sensation. From the data collected, participants had described vertigo in more distinct ways: "*swimming type of movement*" (P01), "*The sky and earth turned upside down*" (P02), "*The turning*

movement is actually flip and flip and flip" (P03), and "*swaying or bobbing up and down*" (P09). Participants also expressed their emotional reactions to this sensation differently. Most reactions were negative with some being adversely affected:

"Really scary. I really scared of the spin that [when] it happened, it will really let you lose control and let you fall." (P03)

"Feels terrible…don't' know how to describe. So dizzy that I cannot sit or stand properly." (P07)

"Last time wah when you got the giddiness … (…) …like the end of the world like that you know. Wah it's very torturing you know." (P08)

"(…) I would say it is very torturing, very, very torturing, like you going to die like that… (…) … when this happens, I always pray to the lord: give me the strength to carry on." (P08)

"Yeah, I hate the sensation." (P12)

7.5.1.2 Needed help or company for activities of daily living and mobility

Most participants reported some difficulty moving around and going about their daily activities following the onset of BPPV symptoms. A small number of participants were able to continue their daily activities independently: "*didn't affect normal life or lifestyle*" and were able to continue daily activities with some modifications (P01, P04 and P09). Others had to "*lie in bed till they felt better*", and needed help with "*bringing over medications*", meal preparation, and household chores (P02, P12, P13). Moreover, there were participants who were adversely affected such that supervision or assistance had to be rendered:

"(…) And I dare not to lie down. I must have somebody with me, hold my hand then I lie down." (P05)

"Even I go [to] toilet [to] take a bath also with somebody like my hubby to help me." (P05)

"I could not do anything. Just sit down on a chair (sofa) all the time. Put bread and water on the table (next to the sofa). Dare not walk to the back (kitchen) at all. No one is at home. My husband must go to work, so I sleep on the sofa till my husband returns from work. I dare not walk about on my own. It was terrible really." (P07)

7.5.1.3 Modification or curtailment of activities and movements

Since vertigo is typically triggered by movements and changes in head positions, especially fast and sudden ones, participants naturally modified or curtailed their movements and activities to avoid triggering vertigo and loss of balance. Common restraints in movement included not turning the head fast, keeping the head straight while reaching high/low or when turning around, and changing positions slowly. Participants also stopped or modified activities that were deemed to trigger vertigo or as a "cause" of BPPV:

"I have this vertigo for the second time, I stopped doing the plank… (…) …I kind of carry the dumbbell. I still have but now I'm not doing because of this problem [sic]… (…)… I try not to do these things because it's a bit stressed, considered as a tough exercise for my problem, not for my age." (P03)

"Once I avoid an activity, I will not want to try it again. I am afraid it will trigger the vertigo again." (P06)

"Like the wall hanging TV, [one] must lift the head up to view it, after which return [lower] the head to position, that will make me dizzy. I cannot look up. I will have to watch the [wall hanging] TV standing up, cannot sit and do so." (P07)

7.5.1.4 Changes in lifestyle/Quality of Life

Disruptions to activities and daily living affected the lifestyle and quality of life of participants. However, these changes varied from individual to individual. A couple of participants were able to continue their lives uninterrupted (P04 and P09) including travelling (P09). One participant (P03) became "*very cautious about oily food*" and started eating more of the "*soup type*". Participants, who normally enjoyed sports, gave up certain types of sports: ball games (P06), planking and weightlifting (P04), and jogging (10). The quality of sleep and rest was also affected (P04, P05 and P07). Work for several participants were disrupted with some having to take medical leave (P06, P10, P12 and P13) and one participant who went into early retirement (P08). One participant also could not visit the hair salon or the dentist because of the reclining positions required during the visits (P07). Leisure activities and hobbies for the participants also came to a halt:

"Yes. I dare not to go out when they have any outdoor…. like go out with my friends all these I [have] stopped." (P05)

"… when I was well, I can do anything. I can bake all kinds of cookies and cakes. But now with the dizziness, I have no desire or inclination to do all these." (P07)

"Cause [Because] I have not been overseas for quite long already because that time I was thinking about my headache, the giddiness and all that, so it doesn't give me the chance to go overseas." (P08)

"But because of this …March found out I have BPPV, I couldn't carry on with my plan to travel to Europe." (P11)

7.5.2 Psycho-emotional and social impacts

7.5.2.1 Negative emotions

Intertwined with the physical and functional problems associated with BPPV was a myriad of emotions experienced by the participants. These emotions ranged from experiencing low moods, feeling upset, anxiety and worries, to self-blame. Several participants mentioned "*my mood was worse when I was dizzy*" (P02), "*it [BPPV] indirectly caused the mood to be very low*" (P06), and "*when it comes to attack me, I [feel] really, really upset*" (P05). Some participants also blamed themselves for the condition: "*I am angry with myself: how did I get this dizziness problem? Why has it not resolved after so long?*" (P07), and "*Why I didn't stop myself from….you know, why did I do this that caused this thing to happen.*" (P12). One participant (P03) was anxious and disappointed when he suffered a recurrence: "*But I don't expect it to be back so fast. One month only. That's why I'm already a bit worried. Don't know why [the recurrence]. The question is a lot, you know for me, WHY, and how am I going to do a job?*"

Disruptions to daily activities and function created anxiety and worries in the participants. As over half of the participants (54%) were still working, some were worried that their need to take sick leave would affect their work:

"I also fear that if it comes, whether I can work or not. If it keeps on attacking me, I [will] have to take leave and take MC [sick leave]. That's the worst part." (P05)

"It affects my life a lot. Especially at that time when I was working, a lot of problems. The headache, the giddiness and then always… it is not nice when you are working and then take MC [sick leave] and all that." (P08)

One participant (P03) who worked as a private hire driver was worried for both his passengers and livelihood: "Now my job is drive, you know I drive and fetch people, I am really worried. If let's say it [vertigo] happens, it's very dangerous. But so far, I don't turn my head so extreme, driving [is] still okay. If you tell people [that] you have this thing…problem, most people will get scared."

A participant extended her thoughts to include others who might be in a worse situation: "*Actually, for my work, I am allowed MC [sick leave], so there isn't much problem encountered. Because I have got the…so I just wonder if someone who needs to take MC [sick leave] and yet, you know…they are not covered, then it might affect their livelihood.*"

Others were concerned over their role and ability to care and provide for their family:

"But to me, it's very important in the sense that, I am a caregiver to my wife. I cannot let deterioration in respect of [sic] my health to go from the beginning to anything bad, I cannot do that sort of thing. I will not allow." (P04)

"Because I have one mother to look after. She is now 85 years old. I need to support her because I engage a maid for her. So, if [BPPV] very often attacks me and I can't do anything, my mom also [will be] worried." (P05)

7.5.2.2 Fear of BPPV attacks and recurrence due to the unpredictable nature

Although BPPV attacks (vertigo episodes) are often triggered by certain head positions and movements, these attacks might still occur unexpectedly. This uncertainty of when vertigo might strike caused participants to be anxious and fearful of the vertiginous events, even causing a loss in confidence:

"When I had the dizziness, I could not go [get] out of the house. I was unsure when the dizziness episode will occur again." (P02)

"Apart from the sudden vertigo, it will also make you fearful. Fear that it may come at any time, causing you to lose your balance and fall down." (P06)

"I have some problems for giddiness and walking is not balanced sometimes and I lost my confidence also." (P11)

Likewise, BPPV recurrence was a topic which the participants were very concerned about. Most participants expressed their fear of recurrence, as well as the inability to predict when BPPV might recur:

"Now I have recovered to 100% but I have no idea when this condition will recur. Hopefully, it will not happen again." (P02)

"There has been lots of improvement. I have no more vertigo. However, there is the fear of it recurring at any point of time once we had it before." (P06)

One participant (P08) was so averse to the notion of a recurrence, he had refused to acknowledge it: "So, I don't wish it [BPPV] will come back. I never thought of that it will come back. It will never… I think it will never. I think it will definitely, definitely be much better". Another participant (P06) mentioned she had tried her best "to avoid those [circumstances or movements] that should be avoided because there is the fear of it recurring at any time" while others wished for a "permanent" solution to BPPV (P03, P04, P05 and P07).

On coping with recurrence, most participants expressed they would be able to cope and know what they need to do. They felt that they would be able to recognise the onset and symptoms of BPPV. One participant (P02) said if the symptoms return, she would be able to *"differentiate between the dizziness caused by inner ear imbalance and the usual dizziness"* because *"they are really different"*. Some participants (P06 and P12) said they would first try the exercises (taught by the physiotherapists) to try *"put the stone back to where it is supposed to be"* before seeking professional help. Most participants chose to visit the Doctor to get a referral to Physiotherapy for further management. One participant (P05) said she totally had no confidence in coping with a recurrence.

7.5.2.3 Family and social support

Some participants mentioned about receiving support from their families during the time they were unwell with BPPV. They highlighted why having such support was important:

"My family members are very understanding towards me. This is very important. Because they know about my condition, they helped to measure my blood pressure and monitored how high it was; they attended to my needs. At that point in time, family support was very important." (P02)

"(…) … my wife is having vertigo. Her form of vertigo and mine are slightly different. From her experience and my experience recently, we talked to one another and exchanged our views as to how we should try to help one another by overcoming vertigo." (P04)

"Luckily, I have got quite good support at home. So, there is no issue. But for someone who has got poor support, a little bit difficult." (P12)

One participant (P06) also talked about support provided by colleagues at work: "Talking about interpersonal relationships, my colleagues would come caring and took care of me when I had the attacks".

On the other spectrum, some participants felt that people around did not understand the problems they faced with BPPV:

"let's say I am getting the spinning sensation… (…) … My thing is I am going around very fast in my head. But somebody looking at me will say "But you look ok. Nothing's happening"… (…) … The person who is not suffering is just looking at the sufferer, cannot understand what is happening: "you look normal but why are you spinning?". They think I am putting up an act…saying I am spinning to get out of the situation, but I am suffering. I cannot show it to you because it's in my brain. That's how it is." (P09)

7.5.3 Treatment and recovery

7.5.3.1 BPPV treatment improved symptoms and physical function

Participants generally found Physiotherapy helpful in alleviating their symptoms and improving physical function (see section 7.3.2 for an overview of the physiotherapy treatments). As a result, their mood and confidence also improved:

"Yes, my condition is very much better than previous time when I am not here at all." (P08)

"Condition changed in that…I am more confident, less fearful because as I said, the feeling of the unsteadiness has shortened." (P09)

"I feel that the physiotherapy is very helpful for these symptoms…. really helped the patients to recover from these symptoms." (P10)

Some participants mentioned they were prescribed medications for their vertigo/dizziness when they first visited the primary healthcare clinics after the onset of BPPV symptoms. These participants (P02, P03 and P04) did not find the drug treatment as helpful in managing their BPPV symptoms. They were subsequently referred to the Otolaryngology Specialist and Physiotherapy for further management.

Despite the improvement in symptoms and physical function, not all participants were back at premorbid status. One participant (P05) said she still had "*no confidence*", and her husband had to "*send and fetch her from work daily*" because she did not know "*when BPPV will come and attack her again*". For others, they were happy if there was improvement and they started to feel better, albeit still having BPPV (P07 and P09). One participant (P07) cited a 70% to 80% improvement in her condition at the time of interview. She mentioned she was "*happier because she felt better*", despite still experiencing some restrictions such as "*unable to look up and down, squat down and wash hair, visit the hair salon and dentist*".

7.5.3.2 Appreciated information on the condition and care

Participants appreciated that their physiotherapists had provided detailed explanation for the assessment and treatment procedures, including the rationale for these procedures. They found the use of visual aids such as the ear model and

progress reports/charts beneficial too. In turn, participants reflected a better understanding of their condition and progress.

"I wish to add on that if the therapist can explain the anatomy and how the condition (pathophysiology) and show the model of the ear to the patient. This helps us to feel more at ease and increases our confidence. It made me worry a lot less about the condition." (P02)

"I know the processes … (…) … At least I understand, yes there is not just my own knowledge that I am improving but I am also seeing it physically that oh there is the chart or some graph to show that yes, I have made some progress compared to let's say November." (P09)

7.5.3.3 Negative patient experiences

Despite the positive experiences discussed earlier, there were also the negative ones that some participants shared. Certain exercises, and even tests, would, inevitably, invoke vertigo/dizziness and hence, made the participants feel sick. Given the unpleasant experience associated with these exercises or tests, it sometimes led to decreased patient compliance:

"Look at "A" and then turn and look at another "A" and turn that side. I don't think I will do the exercise. It makes me more sick." (P01, on gaze stability exercises)

"I don't quite like the box because that's the first thing you do, straight away it's making me giddy. But I think the worst one is when sometimes lying on the bed, I turned the head." (P01, on the Sensory Organisation Test using Neurocom® Balance Master and the positional tests for BPPV)

" I tried to do the brandt-daroff. And not do once, you know, you have to do five times, right? … (…) … it caused me giddiness, the spinning… (…) … My wife asked me on Tuesday, you want to do it again or not? I said today don't want, tomorrow I will do. That's not a joke. That's the spin you know." (P03)

7.5.3.4 Structural and system issues

Apart from the negative experiences discussed above, there were several other issues, encountered by the participants, while seeking treatment for BPPV. In the local context, patients, who wish to see a specialist in the hospitals at subsidised

rates, will need to see a doctor at the local Polyclinic to get a referral before an appointment at the hospital can be made. As one participant (P03) reflected:

"When we have this problem, if you are going to get the specialist to do for you, you have to wait. I remembered my GP tried to book the date. They gave me three months later you know. How can vertigo wait for three months?"

Another participant (P08) too had to wait for three months to see the Otolaryngologist at the hospital. In addition, the referral might be made after 2 to 3 visits to the primary healthcare doctors when it was ascertained that medications for dizziness were not helping the participants (P02, P03 and P04). For the physiotherapy sessions, one participant (P04) mentioned that one could be *"cured as soon as possible"* (of BPPV) if there was *"a shorter space of time [between sessions] for the physiotherapist to attend to the patients".*

Participants also reflected on what they hope to be in place for patients with BPPV:

(i) Early referral to the specialist in the hospital

A participant (P02) felt it would be good if the doctors at the Polyclinic refer the patients early to the specialist to prevent *"unnecessary delay in treatment"*. She also pointed out how information could be provided to the patients: "*The polyclinic doctor should clearly inform the patients that there are more detailed examinations and other appropriate treatment available for dizziness, including Physiotherapy, not the mere use of medications. We need to treat the cause, the root of the problem.*"

(ii) Walk-in treatment

In addition to the earlier mentioned shorter waiting time between physiotherapy sessions, participants also hoped that in the event of a BPPV attack or recurrence, they would have access to early, immediate treatment:

"*Better only when I call and straightaway, I can come here to do Physiotherapy. It [otoconia] can put it back. Sometimes because there is no space, no vacancy… (…) … for me is suffering.*" (P05)

"*It would be good if you have walk in clinic… (…) … you can just pop in… you know, to get it corrected.*" (P12)

(iii) Doctors in the primary healthcare sector to be able to manage BPPV

One participant (P03) felt that doctors in the Polyclinics or General Practitioner clinics should be able to treat BPPV too: "*if I am saying for the normal people, not everybody will get it, then there's no choice. If everyone can have it, I think like what I said, GP needs to also know how to do it, not only for the specialists*". He went on further to provide his rationale: "*Let's say you have this vertigo… (…) … You have to wait for the specialist to do [treat] for you. If don't have [available specialist or appointment], then how? keep waiting? (…) You know the medicine to prevent giddiness is not the solution*".

7.5.4 BPPV literacy

7.5.4.1 Understanding of BPPV

In general, most participants were able to identify the pathomechanism, causes, symptoms, and treatment of BPPV:

"There are some crystals in my inner ear, so if it's out of the normal place where it's supposed to be, then it will cause all these balance problems. Yeah, this vertigo." (P12)

"I was fully convinced of this treatment after I understood the rationale behind this type of treatment. Why must turn this way, that way, move up this way? The aim is to move the crystals along and out of the canal. I have learned something." (P03)

"Nice to know that this is not a life threatening sort of sickness. But it is something that can happen to anyone." (P04)

However, there might be some misunderstanding or misperception as well. One participant (P11) said this "*So I understand that from that…now I am not have [having] a vertigo, I have a BPPV*". Another participant highlighted the reason why it was difficult for him as a lay person to fully understand and differentiate BPPV from other conditions that also cause vertigo:

"Because of my vertigo issues at that time and I didn't know there were so many different levels to the condition. And mine was identified as "BPPV", which of course was completely alien to me until I was given the name and I googled it on the internet… (…) … I am not too sure when all these terms came about but like I said,

they were all alien to me being a layman. Totally unfamiliar with such medical terms and all the different nuances or slight differences to call it a different condition." (P09)

7.5.4.2 Increase public awareness of BPPV

Many participants felt the need to share what they learnt of BPPV and to improve public awareness of this condition. One participant (P03) mentioned she wanted "*more people to benefit from the study by participating in the [this] study*". Others felt they wanted to share the knowledge of BPPV so that other people might cope better in the event of occurrence:

"Because we are all growing into this age range and may experience such a problem. By sharing my knowledge with them, it might be of help to them." (P06)

"Because they [BPPV] can come and go whatever but they [other people] know how to take care of themselves. They won't suffer so long." (P11)

The same participant (P11) also suggested conducting public seminars to educate people of all ages about BPPV so to *"help the public understand what is BPPV – to help people to recognise earlier they have it [BPPV]"*.

Further suggestions were made on how information on BPPV could be made available in different languages and in a common, non-medical way to improve public knowledge:

"Usually, we hardly come across information on inner ear imbalance [problem]). No, we don't. We may have heard the term "Inner ear imbalance" but we do not understand what the actual problem entails… (…) … Such information sharing should be done in other languages, other than English, so more people can benefit from it." (P02)

"Some senior citizens, we can use a very simple thing [language] to let them know, to understand. Use very simple words, not so complicated in the medical term [terms]." (P11)

7.6 Discussion

This qualitative study has presented the experiences of older adults with BPPV and how the condition had impacted on them. Thirteen participants, aged between 55 and 79 years old, took part in these semi-structured interviews. The evidence from this study adds to the limited literature on patient experiences with vestibular conditions, and specifically with BPPV.

From the results, it is evident that patients with BPPV can experience vertigo differently from the classic “spinning”. One participant even reported experiencing mainly unsteadiness or as “swaying” while other participants had described the sensation as “swimming”, “flipping” and “things falling on you”. Studies had previously found that older adults had the tendency to describe their symptoms as unsteadiness and non-specific dizziness (Batuecas-Caletrio et al., 2013; Piker & Jacobson, 2014; Plodpai et al., 2014). In addition, there is also evidence of avoidance or curtailment of certain activities and movements amongst the participants in their bid to prevent triggering vertigo. These phenomena make it harder for healthcare professionals to identify BPPV symptoms and pose a barrier to early detection and treatment of BPPV. Hence, healthcare professionals should be mindful of these presentations when attending to older adults with complaints of dizziness or falls. A detailed history taking is integral in first uncovering possible signs of BPPV. This allows for early diagnosis and treatment of BPPV which will, in turn, prevent the undesirable consequences of physical deterioration and falls.

While BPPV is commonly known to be easily treated and non-lethal, its occurrence affected the physical and psycho-emotional health substantially in some of the participants in this study. There were moderate disruptions to daily activities, work, and leisure activities, which inevitably led to a decreased quality of life for them. With treatment, the participants reported improvement in their symptoms and physical functions. These qualitative findings are congruent with the quantitative findings from the Cross-sectional studies 1 and 2 (Chapter 5). Current management of BPPV includes repositioning manoeuvres and often, the addition of Vestibular Rehabilitation (vestibular and balance exercises). However, there may be a lack of focus on the psycho-emotional sequelae of BPPV. Studies have reported negative emotions and increased levels of anxiety in subjects with BPPV (Gunes & Yuzbasioglu, 2019; Kahraman et al., 2017; Pollak et al., 2012). There is also evidence of anxiety levels decreasing with improvement post treatment (Gunes &

Yuzbasioglu, 2019; Kahraman et al., 2017). However, such negative emotions may persist in some people with BPPV despite being effectively treated (Gunes & Yuzbasioglu, 2019; Kahraman et al., 2017; Pollak et al., 2012) and this may contribute to residual dizziness in some patients (Giommetti et al., 2017; N. H. Lee et al., 2009). It may be beneficial if clinicians screen and monitor patients with BPPV for possible anxiety or coping problems. There is also the need for further research on a suitable screening tool for clinical use in such patient groups. Most participants in the present study, though expressed anxiety, and negative feelings in relation to BPPV, also felt that they would be prepared to cope should recurrences happen. Prior experiences with BPPV attacks and rehabilitation might have aided in forming realistic expectations and knowing what to do “when the time comes”.

Falls and increased falls risk are common problems faced by older adults. With BPPV being more prevalent in this population group, the risk of falls further increases. Although only one participant in this qualitative study reported to have experienced actual falls, the fear of falling, in relation to vertigo and unsteadiness, was highlighted by many. The recent updated BPPV Clinical Practice Guideline by the American Academy of Otolaryngology—Head and Neck Surgery Foundation (AAO-HNSF) (Bhattacharyya et al., 2017) advocates that the assessment for falls risk should be part of the evaluation process for patients with BPPV, especially in the older adult population. The guideline also included the need to provide advice or counselling on BPPV related falls risk and falls prevention measures, at initial diagnosis of BPPV, to both the patients and caregivers. It is also important to implement suitable therapeutic or Vestibular Rehabilitation exercises, in addition to repositioning manoeuvres, based on the specific needs of the patients.

Early BPPV detection and treatment are important to minimise undesirable physical and psycho-emotional consequences. Previous studies reported prevalence of 9% and 11% of unrecognised BPPV amongst community-dwelling older adults (Lena Kollén et al., 2012; Oghalai et al., 2000). These studies also found that despite experiencing dizziness and/or unsteadiness, most of these subjects did not consult or inform their physicians on these issues. One qualitative study of older adults with dizziness reported similar findings – that dizziness was often not the main reason why the older adults went to see their doctors (Stam et al., 2016). Instead, dizziness was presented as a secondary complaint. The interviewees felt that the problem might not be serious enough, or that there was nothing much the doctors could do

about it. On the other hand, another study found that 89% of physicians (both primary and specialty health providers) did not evaluate patients with dizziness for BPPV (Polensek, Sterk, & Tusa, 2008). In the present study, there was a general good understanding of BPPV amongst the participants as most had experienced BPPV before. However, similar delays in seeking medical help and similar clinical encounters were also evident in some of the accounts. Some participants in the present study reflected that it took them up to four months, from time of their first medical consultations, to receive the appropriate treatment for BPPV (either by the hospital specialists or the physiotherapists). These participants also mentioned they were prescribed medications for their dizziness and told to try for a couple of weeks before referrals to see the Otolaryngologist were made. A physiotherapy appointment would mean an even longer waiting time. As such, one participant suggested that doctors in the primary health setting such as the Polyclinics and General Practitioner clinics be trained to be able to manage this often easily treatable condition.

The idea of BPPV being managed more at the primary health setting holds many benefits. Patients with BPPV will receive early treatment and with more convenience. Long term healthcare costs may lessen and the specialists in tertiary care will have more time for more complex cases. However, this scenario may not yet be possible. A Dutch study (van Vugt, Diaz Nerio, van der Wouden, van der Horst, & Maarsingh, 2017) on the use of Epley Manoeuvre and Vestibular Rehabilitation by General Practitioners (GP) on patients with vertigo revealed that 57.3% of the GPs surveyed used Epley Manoeuvre to treat patients. Of this group of doctors, 74% performed the treatment themselves while 26% referred the patients for the treatment, predominantly to the physiotherapists. The most common reason cited by the Dutch GPs for not using Epley Manoeuvre, was that they did not know how to perform it. In a retrospective study looking at primary care health services utilisation by patients with vertigo (Grill, Strupp, Müller, & Jahn, 2014), patients with BPPV were mostly treated with medications (53.5%) while 43% had physiotherapy, before they were being referred to the specialised tertiary balance clinics. A survey of 80 physiotherapists, who were interested in Vestibular Rehabilitation in the United Kingdom, found that while most had good awareness of the assessment and treatment for Posterior Canal BPPV, this was not true for the management of the other canals (Male, Ramdharry, Davies, & Beith, 2018). The level of awareness for

the precautions for the positional tests and the characteristics of nystagmus for diagnostic purpose were also poor. Only 28% were aware of the available clinical guidelines for BPPV. Much more efforts with appropriate training and support are needed to enable the management of BPPV at the primary care level. There is currently no local data on how primary care physicians or physiotherapists are managing patients with BPPV. It would also be beneficial to know the facilitators and barriers for the management of this group of patients at the primary care setting.

Patient education should be part of BPPV management, and this is consistent with the recommendation made in the AAO-HNSF BPPV Clinical Practice Guideline (Bhattacharyya et al., 2017). A study on emotional reactions and beliefs in people with BPPV found that the understanding of one's condition or disease was correlated with the beliefs in one's personal control ($r = 0.3$, $p = .03$) as well as treatment control of the condition ($r = 0.6$, $p < .001$) (Pollak et al., 2012). This is consistent with the findings of this qualitative study. The participants felt reassured knowing what they were suffering from. They also understood what the assessment and treatment entailed, including the rationale behind it. One participant remarked because she understood why and what the management was, she was happy to comply with it. Patient education, in this context, not only helped to empower and enable patients in managing their conditions but also improved patient compliance to the intended management.

Several participants had highlighted the need to educate the people around them and the public about BPPV. Given the increased prevalence of BPPV in older adults and with an ageing population locally in Singapore, the need to increase the public awareness on BPPV could not be timelier and more necessary. Many people, including older adults, attribute dizziness and vertigo to be part of the ageing process. As such, many do not seek appropriate medical attention for the problem and continue to live with the dizziness. In the long term, this can lead to undesirable consequences such as activity curtailment, deconditioning, recurrent falls, physical injuries, and even death. By educating the public and increasing their awareness of BPPV, there may be early recognition of BPPV symptoms, improved vigilance of one's safety and falls prevention, and early seeking of medical attention. In turn, the outcomes may be timely treatment resulting in early return to function, emotional resilience, and improved adaptation to BPPV. Accurate diagnosis and timely treatment of BPPV will also result in lower healthcare costs.

Clinical Implications and Recommendations

- Older adults with BPPV may not describe the classic spinning sensation of vertigo. They may also subconsciously restrict their movements to prevent feeling dizzy. Hence clinicians should conduct careful detailed history taking for patients with dizziness to guide physical examination and aid accurate diagnosis.
- BPPV may be easily treated and non-life threatening. However, older adults with BPPV do experience moderate physical impairments with increased falls risk, and emotional disturbances, and recurrence of BPPV. Hence, management for this population should aim to not just resolve BPPV and ameliorate symptoms, but also to restore physical functions, and prevent falls and undesirable emotional sequelae.
- BPPV is one of the most common causes of dizziness in older adults. There is a need to increase the public awareness of BPPV to enable early recognition of signs and symptoms, and early medical attention/treatment.
- Proper patient education is integral in facilitating and empowering patients in coping with and managing the condition.
- There appears to be a demand for the primary health setting to be able to manage BPPV.

Limitations

A limitation for this qualitative study is that the interview schedule was not piloted before actual data collection which potentially affects the reliability and validity of the results. Another limitation is the sample size of 13, albeit no new themes and sub-themes were uncovered for the last couple of interviews when compared with earlier ones. Sampling was aimed for up to saturation point but was limited by the number of participants who consented to being interviewed and withdrawals due to unforeseen circumstances. There is a possibility, given the diverse characteristics of the group, that a bigger sample size might reveal richer information. It would also have been good to have the interviews as a standalone item for the day. However, the interviews had to be scheduled with the follow-up 2 assessment to minimise inconvenience for the participants. Hence the interviews were, at times, a little rushed or time constrained. However, the duration of interviews ranged from 15 minutes to over one hour, which provided opportunity for

overall a rich set of responses across the participants. Participant fatigue could have also influenced the quantity and quality of data obtained.

7.7 Conclusion

This is a qualitative study exploring the experiences of older adults on the impact of BPPV on their lives. BPPV is known to be non-life threatening and often, easily treatable. Despite that, the findings and insights gained point to negative impacts of BPPV on both physical and emotional health, moderate disruptions to their lifestyle and a decreased quality of life for the participants. Current BPPV treatment had brought about subjective improvement in both symptoms and functions for the participants but not all improvements were optimal. The responses from the participants also highlighted the importance of patient education as well as the need to educate the public on this prevalent but little known condition. The results and clinical implications may be useful in informing the need for a broader BPPV management focus to include consideration of physical function, falls risk, and psycho-emotions (especially anxiety) for older adults with BPPV.

The research reported in this chapter was partially supported by the SGH Research Grant - New Investigator Grant (SRG - NIG) (Grant number: SRG-NIG #10/2017; awarded to Dr Dawn Tan, Co-supervisor, and Principal Investigator (SGH).

Chapter 8 Discussion and Conclusion

In this thesis, there was a total of five studies: a systematic review, two cross-sectional studies, a longitudinal study, and a qualitative component. The sample size was 60 older adults aged 55 years old and above – 40 participants with BPPV with up to six months follow-up and 20 comparison control participants. The entire data collection process took place from July 2017 to October 2019. All participants, save for one, completed the six-months follow-up. In this chapter, a summary of the findings of the main thesis findings are presented, along with a brief overview discussion (detailed discussion of each study is included within each chapter). Limitations of the studies in the thesis are summarized, and recommendations for practice and for future research, drawing on the study findings, are also reported.

8.1 Summary of Key Findings

The systematic review (Chapter 3) investigated if there were poor long-term and short-term outcomes in adults with BPPV post repositioning manoeuvres, and if older adults experience different outcomes from younger adults. Thirty-five articles, using observational and experimental studies with a minimum one-month follow-up time, were identified for qualitative synthesis. Nineteen of those articles were included in the meta-analysis. From the qualitative synthesis, it was found that adults with BPPV may face issues such as residual dizziness, recurrences, and mental health sequelae despite successful repositioning manoeuvres. In addition, results from the meta-analysis showed that older adults did not recover as optimally in dynamic balance and had a greater level of self-perceived handicap, when compared with their younger counterparts.

For the cross-sectional studies (Chapter 5), 40 participants with BPPV and 20 comparison control participants took part in the studies. The aims were to compare the physical performance and self-report measures of older adults with BPPV and comparison controls, at baseline and after initial repositioning manoeuvres; and to explore the factors associated with residual dizziness in older adults with BPPV. Comparisons of the results in the physical performance and questionnaire responses were made between the comparison control and the BPPV groups both at study entry (Cross-sectional 1) and after initial repositioning manoeuvres (Cross-sectional

2). Older adults presenting with BPPV fared significantly poorer in gait, balance and balance confidence, and quality of life, compared to comparison control participants at baseline (T0). The effectiveness of the initial repositioning manoeuvres was 45% (18/40), as determined by positive to negative positional test conversion, in this sample of older adults with BPPV. For those who remained positive with BPPV after initial repositioning manoeuvres (22/40), there was a trend towards improvement in some physical and subjective measures over a seven-day period. The result differences between the BPPV-positive and comparison control groups for these measures were no longer significant. An overall improvement (i.e., no significant differences when compared with comparison controls) in all measures was observed for those who tested negative for BPPV on the first follow-up. Further examination of these non-significant results revealed that the MCID of some outcomes approximated the adjusted mean differences. In some instances, the corresponding 95% confidence intervals included the MCID. This implies that the true group differences may be plausibly clinically significant, despite the statistically insignificant results. Future studies with larger sample sizes are needed for more conclusive results. Half of the participants (9/18) who were successfully treated of BPPV reported symptoms of residual dizziness. Age, the number of comorbidities, and the follow-up (T1) VRBQ Anxiety subscale and Geriatric Anxiety Inventory were found to be significantly associated with residual dizziness.

A total of 39 participants with BPPV and 20 control participants completed the six-months follow-up in the longitudinal study (Chapter 6). One participant with BPPV declined to provide data after the second follow-up (T2) despite multiple attempts to contact him. Participants from the comparison control group were only followed up for falls. The main aims were to explore the factors and the longer-term outcomes associated with residual dizziness in older adults post repositioning manoeuvres, and to monitor the trends of recurrence, changes in BPPV status, and falls in older adults with BPPV. Falls data were compared between the BPPV and comparison control groups. The initial effectiveness of the repositioning manoeuvres in older adults with BPPV in this study was only 45%, and the BPPV recurrence rate was 15% over the six months follow-up period. Residual dizziness was reported in up to 60% of the older adults with BPPV who were cleared of BPPV over the six months follow-up period. Residual dizziness was found to be significantly associated with age, anxiety, and depression but not with gender, number of comorbidities, living

arrangements, history of BPPV, and the duration of BPPV symptoms. For measures associated with residual dizziness, self-report handicap, quality of life, balance confidence, and mental health had significant associations. However, gait, balance, and physical activity level were not associated with residual dizziness. Preliminary falls data analysis was inconclusive as this study was not powered to detect the difference in the number of falls between the BPPV and comparison control groups. However, there was some indication of falls being a greater issue in the earlier stages of treatment/recovery in the BPPV group.

A total of 13 participants (from the sample of the earlier cross-sectional and longitudinal studies) took part in the qualitative study (Chapter 7), which aimed to explore the experiences of older adults on the impact of BPPV on their lives. BPPV is generally non-life threatening and can be treated easily. However, the participants revealed negative impacts of BPPV on both physical and emotional health, moderate disruptions to their lifestyle, and a decreased quality of life. Both symptoms and physical functions improved with the current BPPV treatment, though not all improvements were optimal. The responses from the participants also highlighted the importance of both patient and public education on this prevalent, yet relatively unknown condition.

This thesis programme set out to investigate residual dizziness and to gain comprehensive insights into the experiences and treatment outcomes of older adults with BPPV. Overall, albeit the small sample size, the thesis gained some insights and information which may be useful in the management and future research of older adults with BPPV. While less than half of the older adults tested negative for BPPV following initial repositioning manoeuvres, the follow-up treatment over time brought about BPPV resolution in 70% of the participants in one month (T2) and an overall 94% treatment success. Older adults with BPPV also performed poorer in physical performance and self-report measures when compared with older adults without BPPV. These physical and subjective deficits trended towards improvement with treatment. Although there was no difference in the number of falls between the BPPV and comparison control participants over six months, those in the BPPV group trended towards increased falls particularly in the early rehabilitation phase. Fifteen percent of the participants with BPPV experienced recurrence. Residual dizziness was reported in up to 60% of the older adult participants and was associated with age and mental health screening measures. The shared experiences of the

participants revealed the negative impact of BPPV on their lives physically and psycho-emotionally, culminating in decreased quality of life and fear-avoidance behaviours. This corroborated with the quantitative findings; and underscores the importance of addressing possible issues across the physical, functional, and psycho-emotional domains in the management of older adults with BPPV.

8.2 Discussion

In this section, the key findings and implications to future clinical practice and research directions are discussed. A summary of the recommendations to clinical practice and future research is presented in section 8.4.

8.2.1 Effectiveness of repositioning manoeuvres in older adults with BPPV

As discussed in the earlier chapters, repositioning manoeuvres are the current gold standard treatment for BPPV. The efficacies of repositioning manoeuvres have been reported to range from 60% to more than 90%, often within initial treatment sessions (T. D. Fife et al., 2008). In older adults, the evidence has been conflicting with some studies reporting high efficacy (André et al., 2010; Salvinelli et al., 2004) and some reporting otherwise (Babac et al., 2014; Batuecas-Caletrio et al., 2013). The findings in this thesis demonstrated only 45% of the older adult participants tested negative for BPPV at the first follow-up (T1, seven days post baseline assessment) following initial repositioning manoeuvres. At the second follow-up (T2) a month later, 70% of the participants tested negative for BPPV. The overall treatment success was 94% with 15% recurrence rate over six months . This is in agreement with previous studies that reported less than optimal initial efficacy of the repositioning manoeuvres in older adults (Babac et al., 2014; Batuecas-Caletrio et al., 2013; Prokopakis et al., 2013). A recent systematic review and meta-analysis by Laurent et al (2021) found that while the success rate of a single repositioning manoeuvre in older adults (age ≥ 70 years old) was significantly poorer than younger adults (age < 70 years old), the global (overall) treatment efficacy did not differ between the two groups. The same study also found that the older adult group required more manoeuvres (mean of 1.5 vs 1.4, p = .02) and had higher BPPV recurrence (23.2% vs 18.6%, p = .007), compared to the younger group (Laurent et al., 2021).

The current clinical practice guideline on BPPV recommends a reassessment within one month after initial observation or treatment (Bhattacharyya et al., 2017). Given that older adults with BPPV face increased risk of falls associated with vertigo and unsteadiness (Ganança et al., 2006; Gananca et al., 2010; Lindell, Kollén, Johansson, Karlsson, Rydén, Falk Erhag, et al., 2020), and a low initial effectiveness as found in this thesis, the follow-up sessions for older adults may need to be more frequent and spaced within a shorter time, and over a longer period of care. Additionally, it would be beneficial to better understand what factors affect treatment outcomes in older adults with BPPV.

8.2.2 Residual dizziness in older adults with BPPV

Residual dizziness is defined as non-vertiginous dizziness and/or unsteadiness, despite testing negative on positional tests and without positional vertigo (Seok et al., 2008; Teggi et al., 2011). In this thesis, up to 60% of the older adults with BPPV experienced residual dizziness over the entire study period of six months (Chapter 6). To date, there has been a paucity of research on residual dizziness in older adults with BPPV. One major aim of this thesis was to explore the possible factors (demographic and clinical factors) that are associated with residual dizziness in older adults with BPPV. In this present study, possible factors were modelled as independent variables, with VAS dizziness and unsteadiness as separate dependent variables in the regression analyses. Age and anxiety were two factors found to be significantly associated with residual dizziness (Chapters 5 and 6). Anxiety was quantified by the Vestibular Rehabilitation Benefits Questionnaire (VRBQ) Anxiety Subscore and the Geriatric Anxiety Inventory separately. In Chapter 6, the age factor was further explored. Age ≥ 67 years old was significantly associated with residual dizziness while age below 67 years old was not. Depression, quantified by the 15-Item Geriatric Depression Scale (GDS-15), was another significant factor associated with residual dizziness (Chapter 6). The number of comorbidities was a significant factor associated with residual dizziness in Cross-sectional study 2 (Chapter 5) but was not significant in the longitudinal study (Chapter 6). Hence, based on the findings in this thesis, age (≥ 67 years old) and the mental health measures (anxiety and depression) are significant demographic and clinical factors associated with residual dizziness in older adults being treated of BPPV.

Another aim was to investigate which physical and self-report measures were associated with residual dizziness in older adults with BPPV (Chapter 6). The physical and self-report measures were individually modelled as dependent variables, with VAS dizziness and unsteadiness as the independent variable in separate regression models. From the findings, physical measures such as gait and balance, and level of physical activity, were not significantly associated with residual dizziness. The self-report measures were found to be significantly associated with residual dizziness in older adults with BPPV. The self-reported measures included the Vestibular Rehabilitation Benefits Questionnaire (VRBQ) subscores (Total, Anxiety, and Quality of life); Activities-specific Balance Confidence scale (ABC); Geriatric Anxiety Inventory (GAI); and the 15-item Geriatric Depression Scale (GDS-15). The above findings, of both factors and outcomes associated with residual dizziness in older adults, highlighted the complex interactions and relationship between dizziness and mental health status (anxiety/depression), confounded by age (Carmeli, 2015; Staab & Ruckenstein, 2003). While anxiety is better recognized to contribute to residual dizziness in other research, the evidence on age being a factor remains conflicting.

Two recent systematic review and meta-analysis studies (Laurent et al., 2021; Sim et al., 2019) reported inconclusive results regarding residual dizziness in older adults. This is due to the small number of studies available as well as the conflicting results amongst the studies. More studies on residual dizziness in older adults are needed to provide better conclusive evidence on the prevalence and associated risk factors, and guide management for this patient group. In this thesis, self-report measures were associated with residual dizziness while physical performance measures were not. However, the sample size of the study was small, and the results cannot be deemed conclusive. It is also important that future studies investigate the characteristics and the impact of residual dizziness on older adults with BPPV. Better understanding of the impact of residual dizziness will facilitate targeted treatment. But until there is more conclusive evidence, clinicians should take the cautious approach of monitoring older adults with BPPV for residual dizziness; and assess and manage possible psycho-emotional issues, and balance and gait deficits.

8.2.3 Incorporating assessment of other domains in BPPV management

Another concern is while the efficacy of repositioning manoeuvres is commonly established on the amelioration of symptoms and positional test results, the recovery of the older adult with BPPV (physical, functional, and psycho-emotional) may not progress in tandem with those measures. If treatment success is established as mentioned, older adults may not be followed up further once they test negative on positional tests. The results in this thesis showed that despite being effectively treated for their BPPV (as quantified by negative positional test results) at T1 (Chapter 5, section 5.6.3.2), a moderate proportion of older adults continued to experience residual dizziness. Furthermore, comparing the adjusted mean results in gait, balance, and self-report measures of these older adults who were cleared of BPPV with that of the comparison controls, it is plausible that the true between-group differences are clinically significant despite being statistically insignificant in this study. For those who remained positive at T1 follow-up but had comparable physical and self-report performances with that of the comparison controls, there could still be plausible clinically significant between-group differences.

These ongoing deficits in the physical, functional, and mental health domains may need further attention and management. Previous studies had shown that postural stability and mental health (i.e., anxiety) in older adults with BPPV did not normalise despite months after successful treatment (Lanca et al., 2013; Pollak et al., 2012). If left unaddressed, these physical and mental health problems may lead to further adverse consequences for these older adults. Therefore, it is important to not just assess for BPPV, but also include assessments for function, balance, vestibular, and psycho-emotional domains in the management of older adults with BPPV.

8.2.4 Follow-up assessments and treatment

In addition to the points discussed earlier, the assessment for older adults with BPPV may need to be serial to ensure the recovery in the different domains are optimised. As previous studies had shown, gait, balance, and psycho-emotional aspects may not always be normalised with repositioning manoeuvres. Hence, it is integral that the assessments are made early to identify the impairments and limitations to activities and participation. Follow-up assessments may then be made

over time to review the progress especially if treatment is provided for the identified problems.

It was not within the scope of this thesis to investigate vestibular rehabilitation in the management of BPPV. Nonetheless, it cannot be excluded from the discussion. Negative emotions such as anxiety, depression, and avoidance behaviours may need to be referred to the psychologist for further assessment and management. Issues with gait, balance, and persistence of symptoms can be managed with vestibular rehabilitation. As mentioned in Chapter 2, vestibular rehabilitation comprises an array of treatment: movement or habituation exercises, gaze stabilisation exercises, balance exercises, gait and functional retraining, occupational retraining, and falls prevention (Bhattacharyya et al., 2017). Although there exist some evidence supporting the role of vestibular rehabilitation in BPPV management (Bressi et al., 2017; Reza Hoseinabadi et al., 2018), more studies with better quality are needed to determine the benefits of vestibular rehabilitation in BPPV management. The optimal time to initiate vestibular rehabilitation should also be determined with future research: if starting vestibular rehabilitation early in the BPPV management phase is better than initiating it after BPPV resolution?

8.2.5 Falls monitoring and prevention

Benign Paroxysmal Positional Vertigo increases one's risk of falling and this is especially true for older adults (Ganança et al., 2006; Gananca et al., 2010; Oghalai et al., 2000). In this thesis, though there was no significant difference in the number of falls between the BPPV and comparison control participants, participants in the BPPV had more falls particularly in the early treatment phase. The qualitative study findings also provided evidence to the participants' narrative of increased unsteadiness and tendency to fall with BPPV onset and attacks. The clinical practice guideline on BPPV states that the assessment of patients with BPPV should also include the assessment for risk of falls and identification of other falls risk factors (Bhattacharyya et al., 2017). Patients and their families should also be educated on increased falls risk associated with BPPV; and the various fall precaution measures such as home safety assessment, activities restriction, and need for supervision. It also highlighted the importance of patient education on adhering to treatment follow-ups so that the condition is properly managed (Bhattacharyya et al., 2017). There

remains a paucity of data on falls and falls prevention measures in older adults with BPPV.

8.2.6 The experiences of older adults with BPPV

The qualitative study (Chapter 7) exploring the experiences of older adults with BPPV contributes to the literature on BPPV by providing evidence from the patient's perspective. The participants shared their experiences of the impact of BPPV – how they were affected physically, functionally, and psycho-emotionally. They provided personal accounts of their fears and phobia of vertigo and BPPV recurrence; their dependency on others for self-care and day to day activities during the acute period; how their work, social life, and quality of life were affected; their worries of possible recurrence and how it might impact on them; and their recovery process. It is also important to note that many fears and worries had persisted and were expressed when the participants had been cleared of BPPV. The data collected corroborated with the quantitative evidence on the negative impact of vertigo on its sufferers reported elsewhere (Benecke, Agus, Kuessner, Goodall, & Strupp, 2013). That study sample comprised over 4000 participants with various vestibular diagnoses, of which 26.9% had BPPV. The authors reported that over 60% of participants had to have reduced workloads and lost working days. Furthermore, over 4% had to change or quit their jobs due to vertigo (Benecke et al., 2013). In this thesis, the increased anxiety level and decreased quality of life of the older participants with BPPV (quantified by VRBQ Anxiety and Quality of life scores) corroborated with their narrative of anxiety, worries, and fears in the qualitative study. As previously mentioned, it is imperative for clinicians to monitor these patients for negative emotions and provide the necessary support as part of the management.

On a positive note, the participants expressed their appreciation for the knowledge and education on BPPV provided. They felt that understanding what they were suffering from helped to ease their worries and improved their trust in the care they received. They also expressed how they would be happy to share the knowledge and information with their peers given how common and prevalent BPPV is. Public health education on BPPV will increase the awareness of BPPV and aid in early recognition of the condition. This might be crucial in the prevention of falls due to unrecognised and undiagnosed BPPV and allow for the person to seek timely

help. Another point to note is that during the interview, most participants felt they would be able to recognize the signs and symptoms of BPPV should it recur, and that they would know what to do and where to seek help for it. This is an important aspect of why patient education is important – the empowerment and self-efficacy of patient needed for long term management (Dreeben-Irimia, 2010).

8.2.7 Accessibility to treatment for BPPV

The participants in the qualitative study (Chapter 7) also cited structural barriers to early diagnosis and treatment of BPPV: mainly being given medication for vertigo at the primary healthcare setting, delayed recognition and diagnosis of BPPV at the primary healthcare setting, and the referral to the specialists in the hospitals took months. Fife and FitzGerald (2005) found similar issues when they retrospectively reviewed the medical notes of 20 patients with BPPV. The authors suggested the need for a dedicated clinic for BPPV to improve diagnosis and enable early treatment for BPPV (D. Fife & FitzGerald, 2005). This was a suggestion also brought up by the older adult participants during the interviews. They wished for greater and early accessibility in seeking proper management for their vertiginous attacks.

Given the growing ageing population and the increased prevalence of BPPV and its recurrence in older adults, more need to be done to facilitate timely access to proper diagnosis and treatment of BPPV. The healthcare expenditure of diagnosing BPPV alone estimates around $2 billion a year, not including costs related to treatment and loss of income (Bhattacharyya et al., 2017). Apart from improving public and patient awareness of BPPV, engaging, and improving the capabilities of primary care physicians and vestibular therapists in diagnosing and managing this condition are also equally crucial. A review of the processes involved in specialist referrals (ENT or Neuro-otology) may be necessary to cut down on waste processes and facilitate early consultations for these patients.

8.3 Limitations

There are several limitations that need to be considered in interpreting the results of the studies in this thesis. The sample size of 60 (40 participants with BPPV and 20 comparison control participants) was small and did not meet the target sample size of 216 (108 participants in each group, based on the effective sample

size calculation (Chapter 4, section 4.5)). Unfortunately, recruitment rate was initially low, and remained low despite a variety of additional recruitment strategies being utilised and multiple protocol revisions made to improve the recruitment rate. The small sample size affects the reliability and validity of the study results such as those on the recovery/normalisation of various domains (physical, subjective, and mental health) post treatment, and the factors and outcomes associated with residual dizziness. It also limited the analysis and interpretation of the falls data. As such, the studies could be considered exploratory into the areas of residual dizziness and mental health in older adults with BPPV. These results should be interpreted with caution, but they do highlight some interesting findings that may serve as preliminary data and considerations for future studies.

Another limitation was that comprehensive vestibular function data i.e., the Vestibular Evoked Myogenic Potentials (VEMPs – ocular and cervical), the rotatory chair test, the caloric test, and the Video Head Impulse Test (vHIT) were not able to be incorporated into the study. These data would have provided a more complete assessment of the vestibular function and allowed for more in-depth analysis. It was of great fortune and privilege to have the ICS Impulse System on loan (free of charge) for the studies. However, due to a number of circumstances, the RALP and LARP vHIT results data were deemed invalid when the data were reviewed. This may have been overcome with greater time and training opportunities prior to using the equipment in this study, but this was not the case. In the end, only the vHIT data for the horizontal canals were retained and used in the analyses.

Another concern was that a reliable history and/or proper diagnosis, of other vestibular problems, could not be established for some participants (BPPV group) with a history of dizziness or vertigo. Most of these participants never saw the Otolaryngologist for problems with dizziness but mainly consulted the General Practitioners (GP), and hence also had never undergone any vestibular function tests. One such participant was referred for the vestibular function tests during the study period but had adamantly refused.

The sample population in this thesis were older adults who were independent and community ambulant; and using only the walking stick for outdoors if one was required. Hence the results in this thesis are applicable mainly to independent, generally well-functioning older adults, and cannot be generalised to all older adults, especially frailer older adults, or those with multiple other co-morbidities. Future

studies should be conducted for older adults with balance or mobility issues; those who are institutionalised; with frequent falls; or post traumatic head injury.

8.4 Recommendations

Following the discussion (section 8.2) earlier, below is a summary of the recommended changes and directions for future clinical practice and research in the management of older adults with BPPV.

8.4.1 Clinical practice

Based on the findings of this thesis, the following are recommendations made to the current clinical management of older adults with BPPV:

i. Apart from repositioning manoeuvres, initiate early assessment and management for possible vestibular function, gait, and balance deficits. Serial assessments for these domains may be required to ensure recovery is optimised.
ii. Include mental health measures (i.e., screening tests for anxiety and depression) in the assessment/clinical protocol and initiate appropriate intervention as necessary (i.e., refer for further assessment by the relevant discipline; provide emotional support and reassurances).
iii. Assess older adults with BPPV for residual dizziness and possible mental health issues and provide interventions or referrals to address these when identified.
iv. Monitor older adults with BPPV closely for falls, and assess for falls risk, particularly in the early treatment period. Incorporate education on falls prevention strategies, and recommendations or referrals for appropriate interventions for non-BPPV related falls risk factors identified.
v. Proper patient education is integral in empowering patients and improving engagement with interventions. Equip these older adults with the correct knowledge of BPPV and its related management. Help them understand what they are going through and improve their self-efficacy. In turn, these older adults may help increase the awareness of BPPV as they interact with their peers. Holding public education talks is another way to spread awareness of BPPV.
vi. Improving the engagement and vestibular competency of relevant healthcare professionals i.e., General Practitioners and Physiotherapists, in the primary healthcare setting. There are many advantages if BPPV can be identified and

managed at the primary healthcare setting, as opposed to the current practice of referring to an Otolaryngologist in the hospital which can take months. People, especially older adults, with suspected BPPV should be assessed and treated early, before secondary complications associated with activity avoidance and reduced activity become entrenched. In the long run, this could help in reducing healthcare costs.

8.4.2 Future research

The following are recommendations for future research in older adults with BPPV:

i. To identify factors and outcomes/impact associated with residual dizziness in different subgroups of older adults with BPPV.
ii. To study which factors may influence treatment outcomes or the effectiveness of repositioning manoeuvres in different subgroups of older adults with BPPV.
iii. To explore the optimal follow-up duration between treatment sessions for older adults with BPPV.
iv. To investigate if early Vestibular Rehabilitation (VR) (i.e., balance, gait, and vestibular exercises), in addition to repositioning manoeuvres, produces better long-term outcomes than repositioning manoeuvres alone.
v. To explore the best ways for improving the awareness of BPPV for both the public (especially older adults) and health professionals working in the primary health setting, and addressing knowledge gaps on BPPV and related management, through qualitative research i.e., focus group discussion.
vi. Future studies looking into the management of BPPV in older adults should include physical, functional, and mental health measures for a more comprehensive evaluation.
vii. There is a paucity of falls data in older adults with BPPV. More evidence on the impact of BPPV on falls, and effective interventions are needed especially in older adults with BPPV who are frail, institutionalised, or have balance/mobility issues.

8.5 Conclusion

In this thesis, the initial effectiveness of repositioning manoeuvres was found to be low (45%) in older adults with BPPV. Over the study period of 6-7 months, up

to 60% of these participants experienced residual dizziness post successful repositioning manoeuvres. Recurrence rate was 15%. For the moderate proportion of participants who were cleared of BPPV, notwithstanding statistically insignificant between-group differences, it is plausible that they continued to perform subpar clinically to that of the comparison controls in the areas of gait, balance, quality of life, and mental health.

Age ≥ 67 years old and mental health measures (anxiety and depression) were found to be significantly associated with residual dizziness in older adults with BPPV. In exploring possible outcomes that might be influenced by residual dizziness, physical outcomes (gait and balance) and subjective level of physical activity were not significantly associated while self-report measures (Vestibular Rehabilitation Benefits Questionnaire subscores (Total, Anxiety, and Quality of life); Activities-specific Balance Confidence scale; Geriatric Anxiety Inventory; and the 15-item Geriatric Depression Scale) were significantly associated with residual dizziness.

Older adult participants in the qualitative study (in-depth interviews) shared how they were negatively affected by BPPV – physically, functionally, and psycho-emotionally. The importance of patient and public education, and the need for better accessibility to early treatment were two areas highlighted by the participants.

The findings in this study are applicable mainly to independent, generally well-functioning older adults with BPPV. Clinicians should monitor this population group for residual dizziness, falls risk, and deficits in the physical, functional, and mental health areas. Mental health screening and patient education should be incorporated into the management of older adults with BPPV. Early detection and management of these issues may improve the overall outcome of BPPV management. Future adequately powered, good quality studies are needed to confirm the factors and outcomes associated with residual dizziness in older people with BPPV.

References

Abou-Elew, M. H., Shabana, M. I., Selim, M. H., El-Refaei, A., Fathi, S., & Fatth-Allah, M. O. (2011). Residual postural instability in benign paroxysmal positional vertigo. *Audiological Medicine, 9*(1), 8-15. doi:http://dx.doi.org/10.3109/1651386X.2010.537121

Adams, W. C. (2015). Conducting semi-structured interviews. In K. E. Newcomer, H. P. Hatry, & J. S. Wholey (Eds.), Handbook of Practical Program Evaluation (pp. 492-505). doi:https://doi.org/10.1002/9781119171386.ch19

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

Al-Asadi, J., & Al-Lami, Q. (2015). Prevalence and risk factors of benign paroxysmal positional vertigo among patients with dizziness in Basrah, Iraq. *British Journal of Medicine and Medical Research, 7*, 754-761. doi:10.9734/BJMMR/2015/16542

Altman, D. G., & Royston, P. (2006). The cost of dichotomising continuous variables. *BMJ, 332*(7549), 1080. doi:10.1136/bmj.332.7549.1080

Amor-Dorado, J. C., Barreira-Fernandez, M. P., Aran-Gonzalez, I., Casariego-Vales, E., Llorca, J., & Gonzalez-Gay, M. A. (2012). Particle repositioning maneuver versus Brandt-Daroff exercise for treatment of unilateral idiopathic BPPV of the posterior semicircular canal: a randomized prospective clinical trial with short- and long-term outcome. *Otology & Neurotology, 33*(8), 1401-1407. doi:10.1097/MAO.0b013e318268d50a

Anagnostou, E., Kouzi, I., & Spengos, K. (2015). Diagnosis and treatment of anterior-canal benign paroxysmal positional vertigo: A systematic review. *Journal of Clinical Neurology (Korea), 11*(3), 262-267. doi:10.3988/jcn.2015.11.3.262

Andrade, L. R., Lins, U., Farina, M., Kachar, B., & Thalmann, R. (2012). Immunogold TEM of otoconin 90 and otolin - relevance to mineralization of otoconia, and pathogenesis of benign positional vertigo. *Hearing Research, 292*(1-2), 14-25. doi:10.1016/j.heares.2012.07.003

André, A. P. D. R., Moriguti, J. C., & Moreno, N. S. (2010). Conduct after Epley's maneuver in elderly with posterior canal BPPV in the posterior canal. *Brazilian Journal of Otorhinolaryngology, 76*(3), 300-305. doi:10.1590/s1808-86942010000300005

Anson, E., Pineault, K., Bair, W., Studenski, S., & Agrawal, Y. (2019). Reduced vestibular function is associated with longer, slower steps in healthy adults during normal speed walking. *Gait and Posture, 68*, 340-345. doi:10.1016/j.gaitpost.2018.12.016

Appiani, G. C., Catania, G., & Gagliardi, M. (2001). A liberatory maneuver for the treatment of horizontal canal paroxysmal positional vertigo. *Otology & Neurotology, 22*(1), 66-69.

Appiani, G. C., Catania, G., Gagliardi, M., & Cuiuli, G. (2005). Repositioning maneuver for the treatment of the apogeotropic variant of horizontal canal benign paroxysmal positional vertigo. *Otology & Neurotology, 26*(2), 257-260.

Austin, P. C., & Steyerberg, E. W. (2015). The number of subjects per variable required in linear regression analyses. *Journal of Clinical Epidemiology, 68*(6), 627-636. doi:10.1016/j.jclinepi.2014.12.014

Babac, S., & Arsovic, N. (2012). Efficacy of Epley maneuver in treatment of benign paroxysmal positional vertigo of the posterior semicircular canal. *Vojnosanitetski Pregled, 69*(8), 669-674. doi:http://dx.doi.org/10.2298/VSP1208669B

Babac, S., Djeric, D., Petrovic-Lazic, M., Arsovic, N., & Mikic, A. (2014). Why do treatment failure and recurrences of benign paroxysmal positional vertigo occur? *Otology & Neurotology, 35*(6), 1105-1110. doi:10.1097/MAO.0000000000000417

Babyak, M. A. (2009). Rescaling continuous predictors in regression models. *Statistical Tips from the Editors of Psychosomatic Medicine.* Retrieved from http://stattips.blogspot.com/2009/08/rescaling-continuous-predictors-in.html

Baloh, R. W., Furman, J. M., Halmagyi, G. M., & Allum, J. H. (1995). Recent advances in clinical neurotology. *Journal of Vestibular Research, 5*(4), 231-252.

Baloh, R. W., Honrubia, V., & Jacobson, K. (1987). Benign positional vertigo: clinical and oculographic features in 240 cases. *Neurology, 37*(3), 371-378. doi:10.1212/wnl.37.3.371

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

Bazoni, J. A., Mendes, W. S., Meneses-Barriviera, C. L., Melo, J. J., Costa Vde, S., Teixeira Dde, C., & Marchiori, L. L. (2014). Physical activity in the prevention of benign paroxysmal positional vertigo: probable association. *International Archives of Otorhinolaryngology, 18*(4), 387-390. doi:10.1055/s-0034-1384815

Benecke, H., Agus, S., Kuessner, D., Goodall, G., & Strupp, M. (2013). The burden and impact of vertigo: Findings from the REVERT patient registry. *Frontiers in Neurology, 4*, 136-136. doi:10.3389/fneur.2013.00136

Bertholon, P., Bronstein, A. M., Davies, R. A., Rudge, P., & Thilo, K. V. (2002). Positional down beating nystagmus in 50 patients: Cerebellar disorders and possible anterior semicircular canalithiasis. *Journal of Neurology Neurosurgery and Psychiatry, 72*(3), 366-372. doi:10.1136/jnnp.72.3.366

Beynon, G. J., Baguley, D. M., & Da Cruz, M. J. (2000). Recurrence, of symptoms following treatment of posterior semicircular canal benign positional paroxysmal vertigo with a particle repositioning manoeuvre. *Journal of Otolaryngology, 29*(1), 2-6.

Bhattacharyya, N., Gubbels, S. P., Schwartz, S. R., Edlow, J. A., El-Kashlan, H., Fife, T., . . . Corrigan, M. D. (2017). Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update). *Otolaryngology-Head and Neck Surgery, 156*(3_suppl), S1-S47. doi:10.1177/0194599816689667

Bilek, L. D., Venema, D. M., Willett, G. M., & Lyden, E. R. (2008). Use of the Human Activity Profile for estimating fitness in persons with arthritis. *Arthritis and Rheumatism, 59*(5), 659-664. doi:10.1002/art.23572

Bisdorff, A., Bosser, G., Gueguen, R., & Perrin, P. (2013). The epidemiology of vertigo, dizziness, and unsteadiness and its links to co-morbidities. *Frontiers in Neurology, 4*(29). doi:10.3389/fneur.2013.00029

Bisdorff, A., von Brevern, M., Lempert, T., & Newman-Toker, D. (2009). Classification of vestibular symptoms: towards an international classification of vestibular disorders. *Journal of Vestibular Research, 19*(1-2), 1-13. doi:10.3233/ves-2009-0343

Bisdorff, A. R., Staab, J. P., & Newman-Toker, D. E. (2015). Overview of the International Classification of Vestibular Disorders. *Neurologic Clinics, 33*(3), 541-550. doi:10.1016/j.ncl.2015.04.010

Blatt, P. J., Georgakakis, G. A., Herdman, S. J., Clendaniel, R. A., & Tusa, R. J. (2000). The effect of the canalith repositioning maneuver on resolving postural instability in patients with benign paroxysmal positional vertigo. *American Journal of Otology, 21*(3), 356-363.

Bohannon, R. W. (1997). Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. *Age and Ageing, 26*(1), 15-19. doi:10.1093/ageing/26.1.15

Bohannon, R. W., & Glenney, S. S. (2014). Minimal clinically important difference for change in comfortable gait speed of adults with pathology: a systematic review. *Journal of Evaluation in Clinical Practice, 20*(4), 295-300. doi:10.1111/jep.12158

Bonner, A., Wellard, S., & Kenrick, M. (2006). Development and validation of the Human Activity Profile into Chinese language: lessons in determining equivalence. *Nursing & Health Sciences, 8*(1), 36-43. doi:10.1111/j.1442-2018.2006.00265.x

Brandt, T., & Daroff, R. B. (1980). Physical therapy for benign paroxysmal positional vertigo. *Archives of Otolaryngology, 106*(8), 484-485. doi:10.1001/archotol.1980.00790320036009

Brandt, T., Huppert, D., Hecht, J., Karch, C., & Strupp, M. (2006). Benign paroxysmal positioning vertigo: A long-term follow-up (6-17 years) of 125 patients. *Acta Oto-Laryngologica, 126*(2), 160-163. doi:10.1080/00016480500280140

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77-101. doi:10.1191/1478088706qp063oa

Bressi, F., Vella, P., Casale, M., Moffa, A., Sabatino, L., Lopez, M. A., . . . Sterzi, S. (2017). Vestibular rehabilitation in benign paroxysmal positional vertigo: Reality or fiction? *International Journal of Immunopathology and Pharmacology, 30*(2), 113-122. doi:10.1177/0394632017709917

Bronstein, A. M., Patel, M., & Arshad, Q. (2015). A brief review of the clinical anatomy of the vestibular-ocular connections-how much do we know? *Eye (London, England), 29*(2), 163-170. doi:10.1038/eye.2014.262

Bruintjes, T. D., Companjen, J., van der Zaag-Loonen, H. J., & van Benthem, P. P. G. (2014). A randomised sham-controlled trial to assess the long-term effect of the Epley manoeuvre for treatment of posterior canal benign paroxysmal positional vertigo. *Clinical Otolaryngology, 39*(1), 39-44. doi:http://dx.doi.org/10.1111/coa.12217

Burker, E. J., Wong, H., Sloane, P. D., Mattingly, D., Preisser, J., & Mitchell, C. M. (1995). Predictors of fear of falling in dizzy and nondizzy elderly. *Psychology and Aging, 10*(1), 104-110. doi:10.1037/0882-7974.10.1.104

Buuren, S., & Groothuis-Oudshoorn, C. (2011). MICE: Multivariate Imputation by Chained Equations in R. *Journal of Statistical Software, 45*. doi:10.18637/jss.v045.i03

Cakir, B. O., Ercan, I., Cakir, Z. A., Civelek, S., Sayin, I., & Turgut, S. (2006). What is the true incidence of horizontal semicircular canal benign paroxysmal positional vertigo? *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery, 134*(3), 451-454. doi:10.1016/j.otohns.2005.07.045

Caldas, M. A., Gananca, C. F., Gananca, F. F., Gananca, M. M., & Caovilla, H. H. (2009). Clinical features of benign paroxysmal positional vertigo. *Brazilian Journal of Otorhinolaryngology, 75*(4), 502-506.

Carmeli, E. (2015). Anxiety in the elderly can be a vestibular problem. *Frontiers in public health, 3*, 216-216. doi:10.3389/fpubh.2015.00216

Casani, A. P., Cerchiai, N., Dallan, I., & Sellari-Franceschini, S. (2011). Anterior canal lithiasis: Diagnosis and treatment. *Otolaryngology - Head and Neck Surgery, 144*(3), 412-418. doi:http://dx.doi.org/10.1177/0194599810393879

Casani, A. P., Nacci, A., Dallan, I., Panicucci, E., Gufoni, M., & Sellari-Franceschini, S. (2011). Horizontal semicircular canal benign paroxysmal positional vertigo: effectiveness of two different methods of treatment. *Audiology and Neuro-Otology, 16*(3), 175-184. doi:http://dx.doi.org/10.1159/000317113

Casani, A. P., Navari, E., Albera, R., Agus, G., Asprella Libonati, G., Chiarella, G., . . . califano, l. (2019). Approach to residual dizziness after successfully treated benign paroxysmal positional vertigo: effect of a polyphenol compound supplementation. *Clinical Pharmacology: Advances and Applications, 11*, 117-125. doi:10.2147/cpaa.s210763

Casani, A. P., Vannucci, G., Fattori, B., & Berrettini, S. (2002). The treatment of horizontal canal positional vertigo: Our experience in 66 cases. *Laryngoscope, 112*(1), 172-178.

Celebisoy, N., Polat, F., & Akyurekli, O. (2008). Clinical features of benign paroxysmal positional vertigo in western Turkey. *European Neurology, 59*(6), 315-319. doi:http://dx.doi.org/10.1159/000121422

Cetin, Y. S., Ozmen, O. A., Demir, U. L., Kasapoglu, F., Basut, O., & Coskun, H. (2018). 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 Journal of Medical Sciences, 34*(3), 558-563. doi:10.12669/pjms.343.14786

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

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

Chen, J., Zhao, W., Yue, X., & Zhang, P. (2020). Risk factors for the occurrence of benign paroxysmal positional vertigo: A systematic review and meta-analysis. *Frontiers in Neurology, 11*(506). doi:10.3389/fneur.2020.00506

Chen, Y., Zhuang, J., Zhang, L., Li, Y., Jin, Z., Zhao, Z., . . . Zhou, H. (2012). Short-term efficacy of Semont maneuver for benign paroxysmal positional vertigo: a double-blind randomized trial. *Otology & Neurotology, 33*(7), 1127-1130. doi:10.1097/MAO.0b013e31826352ca

Chiou, W. Y., Lee, H. L., Tsai, S. C., Yu, T. H., & Lee, X. X. (2005). A single therapy for all subtypes of horizontal canal positional vertigo. *Laryngoscope, 115*(8), 1432-1435. doi:10.1097/01.mlg.0000168092.91251.d3

Choi, K., Jeon, G. S., & Cho, S. I. (2017). Prospective study on the impact of fear of falling on functional decline among community dwelling elderly women. *International Journal of Environmental Research and Public Health, 14*(5), 469. doi:10.3390/ijerph14050469

Choung, Y. H., Shin, Y. R., Kahng, H., Park, K., & Choi, S. J. (2006). 'Bow and lean test' to determine the affected ear of horizontal canal benign paroxysmal positional vertigo. *Laryngoscope, 116*(10), 1776-1781. doi:10.1097/01.mlg.0000231291.44818.be

Choy, N. L., Brauer, S., & Nitz, J. (2003). Changes in postural stability in women aged 20 to 80 years. *Journals of Gerontology. Series A: Biological Sciences and Medical Sciences, 58*(6), 525-530. doi:10.1093/gerona/58.6.m525

Chua, K., Re, G., & S, S. (2020). Demographic and clinical characteristics of BPPV patients: a retrospective large cohort study of 1599 patients. *Journal of Otolaryngology-ENT Research, 12*(1), 20-30. doi:10.15406/joentr.2020.12.00451

Chui, K., Hood, E., & Klima, D. (2012). Meaningful change in walking speed. *Topics in Geriatric Rehabilitation, 28*(2), 97-103. doi:10.1097/TGR.0b013e3182510195

Ciorba, A., Cogliandolo, C., Bianchini, C., Aimoni, C., Pelucchi, S., Skarżyński, P. H., & Hatzopoulos, S. (2019). Clinical features of benign paroxysmal positional vertigo of the posterior semicircular canal. *SAGE open medicine, 7*, 2050312118822922-2050312118822922. doi:10.1177/2050312118822922

Cohen, H., Blatchly, C. A., & Gombash, L. L. (1993). A study of the clinical test of sensory interaction and balance. *Physical Therapy, 73*(6), 346-351; discussion 351-344. doi:10.1093/ptj/73.6.346

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

Cohen, H. S., & Kimball, K. T. (2005). Effectiveness of treatments for benign paroxysmal positional vertigo of the posterior canal. *Otology & Neurotology, 26*(5), 1034-1040. doi:10.1097/01.mao.0000185044.31276.59

Coleman, C. I., Sobieraj, D. M., & Marinucci, L. N. (2012). Minimally important clinical difference of the Timed 25-Foot Walk Test: results from a randomized

controlled trial in patients with multiple sclerosis. *Current Medical Research and Opinion, 28*(1), 49-56. doi:10.1185/03007995.2011.639752

Curthoys, I. S. (2020). Concepts and physiological aspects of the otolith organ in relation to electrical stimulation. *Audiology and Neurotology, 25(suppl 1-2)*(1-2), 25-34. doi:10.1159/000502712

Curthoys, I. S., & Manzari, L. (2017). Clinical application of the head impulse test of semicircular canal function. *Hearing, Balance and Communication, 15*(3), 113-126. doi:10.1080/21695717.2017.1353774

Da Silva, C. N., De Figueiredo Ribeiro, K. M. O. B., De Medeiros Freitas, R. V., De Britho Macedo Ferreira, L. M., & Guerra, R. O. (2016). Vertiginous symptoms and objective measures of postural balance in elderly people with benign paroxysmal positional vertigo submitted to the epley maneuver. *International Archives of Otorhinolaryngology, 20*(1), 61-68. doi:http://dx.doi.org/10.1055/s-0035-1565915

Daughton, D. M., Fix, A. J., Kass, I., Bell, C. W., & Patil, K. D. (1982). Maximum oxygen consumption and the ADAPT quality-of-life scale. *Archives of Physical Medicine and Rehabilitation, 63*(12), 620-622.

Davalos-Bichara, M., & Agrawal, Y. (2014). Normative results of healthy older adults on standard clinical vestibular tests. *Otology & neurotology : official publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology, 35*(2), 297-300. doi:10.1097/MAO.0b013e3182a09ca8

Davidson, M., & de Morton, N. (2007). A systematic review of the Human Activity Profile. *Clinical Rehabilitation, 21*(2), 151-162. doi:10.1177/0269215506069475

de Moraes, S. A., Soares, W. J., Ferriolli, E., & Perracini, M. R. (2013). Prevalence and correlates of dizziness in community-dwelling older people: a cross sectional population based study. *BMC Geriatrics, 13*, 4. doi:10.1186/1471-2318-13-4

Del Rio, M., & Arriaga, M. A. (2004). Benign positional vertigo: Prognostic factors. *Otolaryngology - Head and Neck Surgery, 130*(4), 426-429. doi:http://dx.doi.org/10.1016/j.otohns.2003.12.015

Deshpande, N., Metter, E. J., Bandinelli, S., Lauretani, F., Windham, B. G., & Ferrucci, L. (2008). Psychological, physical, and sensory correlates of fear of falling and consequent activity restriction in the elderly: the InCHIANTI study. *American Journal of Physical Medicine and Rehabilitation, 87*(5), 354-362. doi:10.1097/PHM.0b013e31815e6e9b

Devaiah, A. K., & Andreoli, S. (2010). Postmaneuver restrictions in benign paroxysmal positional vertigo: an individual patient data meta-analysis. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery, 142*(2), 155-159. doi:10.1016/j.otohns.2009.09.013

Di Girolamo, S., Paludetti, G., Briglia, G., Cosenza, A., Santarelli, R., & Di Nardo, W. (1998). Postural control in benign paroxysmal positional vertigo before and after recovery. *Acta Oto-Laryngologica, 118*(3), 289-293.

Dispenza, F., Mazzucco, W., Mazzola, S., & Martines, F. (2019). Observational study on risk factors determining residual dizziness after successful benign paroxysmal positional vertigo treatment: the role of subclinical BPPV. *Acta Otorhinolaryngologica Italica, 39*(5), 347-352. doi:10.14639/0392-100X-2247

Dix, M. R., & Hallpike, C. S. (1952). The pathology symptomatology and diagnosis of certain common disorders of the vestibular system. *Proceedings of the Royal Society of Medicine, 45*(6), 341-354.

Dow, B., Lin, X., Pachana, N. A., Bryant, C., LoGiudice, D., A, M. Y. G., & Haralambous, B. (2018). Reliability, concurrent validity, and cultural adaptation of the Geriatric Depression Scale and the Geriatric Anxiety Inventory for detecting depression and anxiety symptoms among older Chinese immigrants: an Australian study. *International Psychogeriatrics, 30*(5), 735-748. doi:10.1017/S1041610217002332

Dreeben-Irimia, O. (2010). *Patient education in rehabilitation / Olga Dreeben*. Sudbury, Mass.: Sudbury, Mass. : Jones and Bartlett Publishers.

Duan, Z., Fu, C., Tang, T., Liu, B., Liu, J., Chen, B., & Zhang, X. (2018). Social support reduces residual dizziness after canalith repositioning procedure in benign paroxysmal positional vertigo. *Biomedical Research, 29*(10), 1988-1993. doi:10.4066/biomedicalresearch.29-17-2987

Dye, D. C., Eakman, A. M., & Bolton, K. M. (2013). Assessing the validity of the dynamic gait index in a balance disorders clinic: an application of Rasch analysis. *Physical Therapy, 93*(6), 809-818. doi:10.2522/ptj.20120163

El-Gabalawy, R., Mackenzie, C., Thibodeau, M., Asmundson, G., & Sareen, J. (2013). Health anxiety disorders in older adults: conceptualizing complex conditions in late life. *Clinical Psychology Review, 33*(8), 1096-1105.

El-Makhzangy, A. M. N. (2015). Benign paroxysmal positional vertigo of lateral semicircular canal: A systematic review and meta-analysis. *Advances in Otolaryngology, 2015*, 465095. doi:10.1155/2015/465095

Epley, J. M. (2006). Human experience with canalith repositioning maneuvers. *Annals of the New York Academy of Sciences, 942*(1), 179-191. doi:10.1111/j.1749-6632.2001.tb03744.x

Escher, A., Ruffieux, C., & Maire, R. (2007). Efficacy of the barbecue manoeuvre in benign paroxysmal vertigo of the horizontal canal. *European Archives of Oto-Rhino-Laryngology, 264*(10), 1239-1241. doi:10.1007/s00405-007-0337-6

Evren, C., Demirbilek, N., Elbistanli, M. S., Kokturk, F., & Celik, M. (2017). Diagnostic value of repeated Dix-Hallpike and roll maneuvers in benign paroxysmal positional vertigo. *Brazilian Journal of Otorhinolaryngology, 83*(3), 243-248. doi:10.1016/j.bjorl.2016.03.007

Faes, C., Molenberghs, G., Aerts, M., Verbeke, G., & Kenward, M. G. (2009). The effective sample size and an alternative small-sample degrees-of-freedom method. *The American Statistician, 63*(4), 389-399. doi:10.1198/tast.2009.08196

Faralli, M., Lapenna, R., Giommetti, G., Pellegrino, C., & Ricci, G. (2016). Residual dizziness after the first BPPV episode: role of otolithic function and of a delayed diagnosis. *European Archives of Oto-Rhino-Laryngology, 273*(10), 3157-3165. doi:10.1007/s00405-016-3947-z

Faralli, M., Ricci, G., Ibba, M. C., Crognoletti, M., Longari, F., & Frenguelli, A. (2009). Dizziness in patients with recent episodes of benign paroxysmal positional vertigo: Real otolithic dysfunction or mental stress? *Journal of Otolaryngology - Head and Neck Surgery, 38*(3), 375-380. doi:10.2310/7070.2009.080073

Farrell, L., & Rine, R. M. (2014). Differences in symptoms among adults with canal versus otolith vestibular dysfunction: A preliminary report. *ISRN rehabilitation, 2014*, 1-10. doi:10.1155/2014/629049

Fife, D., & FitzGerald, J. E. (2005). Do patients with benign paroxysmal positional vertigo receive prompt treatment? Analysis of waiting times and human and financial costs associated with current practice. *International Journal of Audiology, 44*(1), 50-57. doi:10.1080/14992020400022629

Fife, T. D., Iverson, D. J., Lempert, T., Furman, J. M., Baloh, R. W., Tusa, R. J., . . . Gronseth, G. S. (2008). Practice parameter: Therapies for benign paroxysmal positional vertigo (an evidence-based review): Report of the quality standards subcommittee of the American academy of neurology. *Neurology, 70*(22), 2067-2074. doi:10.1212/01.wnl.0000313378.77444.ac

Fong, E., Li, C., Aslakson, R., & Agrawal, Y. (2015). Systematic review of patient-reported outcome measures in clinical vestibular research. *Archives of Physical Medicine and Rehabilitation, 96*(2), 357-365. doi:10.1016/j.apmr.2014.09.017

Ford-Smith, C. D., Wyman, J. F., Elswick, R. K., Jr., Fernandez, T., & Newton, R. A. (1995). Test-retest reliability of the sensory organization test in noninstitutionalized older adults. *Archives of Physical Medicine and Rehabilitation, 76*(1), 77-81. doi:10.1016/s0003-9993(95)80047-6

Freeman, M. F., & Tukey, J. W. (1950). Transformations related to the angular and the square root. *Annals of Mathematical Statistics, 21*(4), 607-611. doi:10.1214/aoms/1177729756

Fritz, S., & Lusardi, M. (2009). White paper: "walking speed: the sixth vital sign". *Journal of Geriatric Physical Therapy, 32*(2), 46-49.

Froehling, D. A., Bowen, J. M., Mohr, D. N., Brey, R. H., Beatty, C. W., Wollan, P. C., & Silversteev, M. D. (2000). The canalith repositioning procedure for the treatment of benign paroxysmal positional vertigo: A randomized controlled trial. *Mayo Clinic Proceedings, 75*(7), 695-700.

Gamiz, M. J., & Lopez-Escamez, J. A. (2004). Health-related quality of life in patients over sixty years old with benign paroxysmal positional vertigo. *Gerontology, 50*(2), 82-86. doi:http://dx.doi.org/10.1159/000075558

Ganança, F. F., Gazzola, J. M., Aratani, M. C., Perracini, M. R., & Ganança, M. M. (2006). Circumstances and consequences of falls in elderly people with vestibular disorder. *Brazilian Journal of Otorhinolaryngology, 72*(3), 388-392. doi:10.1016/s1808-8694(15)30974-5

Gananca, F. F., Gazzola, J. M., Gananca, C. F., Caovilla, H. H., Gananca, M. M., & Cruz, O. L. (2010). Elderly falls associated with benign paroxysmal positional vertigo. *Brazilian Journal of Otorhinolaryngology, 76*(1), 113-120.

Ganz, D. A., Higashi, T., & Rubenstein, L. Z. (2005). Monitoring falls in cohort studies of community-dwelling older people: effect of the recall interval. *Journal of the American Geriatrics Society, 53*(12), 2190-2194. doi:10.1111/j.1532-5415.2005.00509.x

Garaycochea, O., Pérez-Fernández, N., & Manrique-Huarte, R. (2020). A novel maneuver for diagnosis and treatment of torsional-vertical down beating positioning nystagmus: anterior canal and apogeotropic posterior canal BPPV. *Brazilian Journal of Otorhinolaryngology*. doi:10.1016/j.bjorl.2020.09.009

Garratt, A. M., & Stavem, K. (2017). Measurement properties and normative data for the Norwegian SF-36: results from a general population survey. *Health and Quality of Life outcomes, 15*(1), 51. doi:10.1186/s12955-017-0625-9

Gazzola, J. M., Ganança, F. F., Aratani, M. C., Perracini, M. R., & Ganança, M. M. (2006). Circumstances and consequences of falls in elderly people with vestibular disorder. *Brazilian Journal of Otorhinolaryngology, 72*(3), 388-392. doi:10.1016/s1808-8694(15)30974-5

Gerolimatos, L. A., & Edelstein, B. A. (2012). Predictors of health anxiety among older and young adults. *International Psychogeriatrics, 24*(12), 1998-2008. doi:10.1017/s1041610212001329

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

Giommetti, G., Lapenna, R., Panichi, R., Mobaraki, P. D., Longari, F., Ricci, G., & Faralli, M. (2017). Residual dizziness after successful repositioning maneuver for idiopathic benign paroxysmal positional vertigo: A review. *Audiology Research, 7*(1), 178-178. doi:10.4081/audiores.2017.178

GN Otometrics. (2016). ICS Impulse USB: User Guide. [PDF]. *Doc. No. 7-50-2060-EN/02 Part No. 7-50-20600-EN*.

Grill, E., Strupp, M., Müller, M., & Jahn, K. (2014). Health services utilization of patients with vertigo in primary care: a retrospective cohort study. *Official Journal of the European Neurological Society, 261*(8), 1492-1498. doi:10.1007/s00415-014-7367-y

Guan, Q., Han, H., Li, Y., Zhao, L., Jin, L., & Zhan, Q. (2012). Activities-specific Balance Confidence (ABC) scale adapted for the mainland population of China. *Clinical Rehabilitation, 26*(7), 648-655. doi:10.1177/0269215511427748

Gunes, A., & Yuzbasioglu, Y. (2019). Effects of treatment on anxiety levels among patients with benign paroxysmal positional vertigo. *European Archives of Oto-Rhino-Laryngology, 276*(3), 711-718. doi:10.1007/s00405-019-05297-9

Hagr, A. (2009). Comorbid psychiatric conditions of benign paroxysmal positional vertigo. *Int J Health Sci (Qassim), 3*(1), 23-28.

Hain, T. C., & Helminski, J. O. (2014). Anatomy and physiology of the normal vestibular system. In S. J. Herdman & R. A. Clendaniel (Eds.), *Vestibular rehabilitation* (4th ed., pp. 2 - 19). Philadelphia, Pennsylvania: F. A. Davis Company.

Halker, R. B., Barrs, D. M., Wellik, K. E., Wingerchuk, D. M., & Demaerschalk, B. M. (2008). Establishing a diagnosis of benign paroxysmal positional vertigo through the dix-hallpike and side-lying maneuvers: a critically appraised topic. *Neurologist, 14*(3), 201-204. doi:10.1097/NRL.0b013e31816f2820

Hall, C. D., & Herdman, S. J. (2006). Reliability of clinical measures used to assess patients with peripheral vestibular disorders. *Journal of Neurologic Physical Therapy, 30*(2), 74-81. doi:10.1097/01.npt.0000282571.55673.ed

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

Halmagyi, G. M., & Curthoys, I. S. (1988). A clinical sign of canal paresis. *Archives of Neurology, 45*(7), 737-739. doi:10.1001/archneur.1988.00520310043015

Hamid, M. A., Hughes, G. B., & Kinney, S. E. (1991). Specificity and sensitivity of dynamic posturography: A retrospective analysis. *Acta Oto-Laryngologica, 111*(S481), 596-600. doi:10.3109/00016489109131480

Hansson, E. E., Mansson, N. O., & Hakansson, A. (2005). Benign paroxysmal positional vertigo among elderly patients in primary health care. *Gerontology, 51*(6), 386-389. doi:http://dx.doi.org/10.1159/000088702

Harrell, F. E. (2015). *Regression modeling strategies: With applications to linear models, logistic and ordinal regression, and survival analysis*: Springer International Publishing.

Helminski, J. O. (2019). Peripheral downbeat positional nystagmus: Apogeotropic posterior canal or anterior canal BPPV. *Journal of Neurologic Physical Therapy, 43 Suppl 2 Supplement, Special Supplement: International Conference on Vestibular Rehabilitation*(2), S8-S13. doi:10.1097/NPT.0000000000000267

Herdman, S. J., & Hoder, J. M. (2014). Physical therapy management of Benign Paroxysmal Positional Vertigo. In S. J. Herdman & R. A. Clendaniel (Eds.), *Vestibular rehabilitation* (4th ed., pp. 324-358). Philadelphia, Pennsylvania: F. A. Davis Company.

Hillier, S., & McDonnell, M. (2016). Is vestibular rehabilitation effective in improving dizziness and function after unilateral peripheral vestibular hypofunction? An abridged version of a Cochrane Review. *European Journal of Physical and Rehabilitation Medicine, 52*(4), 541-556.

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

Honaker, J. A., Gilbert, J. M., Shepard, N. T., Blum, D. J., & Staab, J. P. (2013). Adverse effects of health anxiety on management of a patient with benign paroxysmal positional vertigo, vestibular migraine and chronic subjective dizziness. *American Journal of Otolaryngology, 34*(5), 592-595. doi:https://doi.org/10.1016/j.amjoto.2013.02.002

Honrubia, V., Baloh, R. W., Harris, M. R., & Jacobson, K. M. (1999). Paroxysmal positional vertigo syndrome. *American Journal of Otology, 20*(4), 465-470.

Hoseinabadi, R., Pourbakht, A., Yazdani, N., Kouhi, A., & Kamali, M. (2016). The effects of abnormality of cVEMP and oVEMP on rehabilitation outcomes in patients with idiopathic benign paroxysmal positional vertigo. *European*

Archives of Oto-Rhino-Laryngology, 273(3), 643-648. doi:http://dx.doi.org/10.1007/s00405-015-3612-y

Hoseinabadi, R., Pourbakht, A., Yazdani, N., Kouhi, A., Kamali, M., Abdollahi, F. Z., & Jafarzadeh, S. (2018). The effects of the vestibular rehabilitation on the benign paroxysmal positional vertigo recurrence rate in patients with otolith dysfunction. *Journal of Audiology & Otology, 22*(4), 204-208. doi:10.7874/jao.2018.00087

Hozo, S. P., Djulbegovic, B., & Hozo, I. (2005). Estimating the mean and variance from the median, range, and the size of a sample. *BMC Medical Research Methodology, 5*(1), 13. doi:10.1186/1471-2288-5-13

Humphriss, R. L., Baguley, D. M., Sparkes, V., Peerman, S. E., & Moffat, D. A. (2003). Contraindications to the Dix-Hallpike manoeuvre: A multidisciplinary review. *International Journal of Audiology, 42*(3), 166-173. doi:10.3109/14992020309090426

Hunt, W. T., Zimmermann, E. F., & Hilton, M. P. (2012). Modifications of the Epley (canalith repositioning) manoeuvre for posterior canal benign paroxysmal positional vertigo (BPPV). *Cochrane Database of Systematic Reviews, 4*(4), CD008675. doi:10.1002/14651858.CD008675.pub2

Igarashi, M., Saito, R., Mizukoshi, K., & Alford, B. R. (1993). Otoconia in young and elderly persons: A temporal bone study. *Acta Oto-Laryngologica, 113*(S504), 26-29. doi:10.3109/00016489309128117

Imai, T., Ito, M., Takeda, N., Uno, A., Matsunaga, T., Sekine, K., & Kubo, T. (2005). Natural course of the remission of vertigo in patients with benign paroxysmal positional vertigo. *Neurology, 64*(5), 920-921. doi:10.1212/01.WNL.0000152890.00170.DA

Imai, T., Takeda, N., Ikezono, T., Shigeno, K., Asai, M., Watanabe, Y., & Suzuki, M. (2017). Classification, diagnostic criteria and management of benign paroxysmal positional vertigo. *Auris, Nasus, Larynx, 44*(1), 1-6. doi:http://dx.doi.org/10.1016/j.anl.2016.03.013

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

Jeon, E. J., Lee, D. H., Park, J. M., Oh, J. H., & Seo, J. H. (2019). The efficacy of a modified Dix-Hallpike test with a pillow under shoulders. *Journal of Vestibular Research, 29*, 197-203. doi:10.3233/VES-190666

Jiang, X., He, L., Gai, Y., Jia, C., Li, W., Hu, S., . . . Cao, L. (2020). Risk factors for residual dizziness in patients successfully treated for unilateral benign posterior semicircular canal paroxysmal positional vertigo. *Journal of International Medical Research, 48*(12), 300060520973093. doi:10.1177/0300060520973093

Johnco, C., Knight, A., Tadic, D., & Wuthrich, V. M. (2015). Psychometric properties of the Geriatric Anxiety Inventory (GAI) and its short-form (GAI-SF) in a clinical and non-clinical sample of older adults. *International Psychogeriatrics, 27*(7), 1089-1097. doi:10.1017/s1041610214001586

Jozefowicz-Korczynska, M., Pajor, A., & Skora, W. (2018). Benign paroxysmal positional vertigo in patients after mild traumatic brain injury. *Advances in Clinical and Experimental Medicine*. doi:10.17219/acem/69708

Jumani, K., & Powell, J. (2017). Benign paroxysmal positional vertigo: Management and its impact on falls. *Annals of Otology, Rhinology and Laryngology, 126*(8), 602-605. doi:10.1177/0003489417718847

Kahlert, J., Gribsholt, S. B., Gammelager, H., Dekkers, O. M., & Luta, G. (2017). Control of confounding in the analysis phase - an overview for clinicians. *Clinical Epidemiology, 9*, 195-204. doi:10.2147/CLEP.S129886

Kahraman, S. S., Arli, C., Copoglu, U. S., Kokacya, M. H., & Colak, S. (2017). The evaluation of anxiety and panic agarophobia scores in patients with benign paroxysmal positional vertigo on initial presentation and at the follow-up visit. *Acta Oto-Laryngologica*, 1-5. doi:http://dx.doi.org/10.1080/00016489.2016.1247986

Kammerlind, A. S., Ledin, T. E., Skargren, E. I., & Odkvist, L. M. (2005). Long-term follow-up after acute unilateral vestibular loss and comparison between subjects with and without remaining symptoms. *Acta Oto-Laryngologica, 125*(9), 946-953. doi:10.1080/00016480510043477

Kantner, C., & Gürkov, R. (2012). Characteristics and clinical applications of ocular vestibular evoked myogenic potentials. *Hearing Research, 294*(1-2), 55-63. doi:10.1016/j.heares.2012.10.008

Kao, C. L., Hsieh, W. L., Chern, C. M., Chen, L. K., Lin, M. H., & Chan, R. C. (2009). Clinical features of benign paroxysmal positional vertigo (BPPV) in Taiwan: differences between young and senior age groups. *Archives of Gerontology and Geriatrics, 49*(SUPPL.2), S50-S54. doi:http://dx.doi.org/10.1016/S0167-4943%2809%2970014-7

Karlberg, M., Hall, K., Quickert, N., Hinson, J., & Halmagyi, G. M. (2000). What inner ear diseases cause benign paroxysmal positional vertigo? *Acta Oto-Laryngologica, 120*(3), 380-385. doi:10.1080/000164800750000603

Kasse, C. A., Santana, G. G., Branco-Barreiro, F. C., Scharlach, R. C., Gazzola, J. M., Gananca, F. F., & Dona, F. (2012). Postural control in older patients with benign paroxysmal positional vertigo. *Otolaryngology and Head and Neck Surgery, 146*(5), 809-815.

Katsarkas, A. (1999). Benign paroxysmal positional vertigo (BPPV): idiopathic versus post-traumatic. *Acta Oto-Laryngologica, 119*(7), 745-749. doi:10.1080/00016489950180360

Kaur, J., & Shamanna, K. (2017). Management of benign paroxysmal positional vertigo: A comparative study between Epleys manouvre and Betahistine. *International Tinnitus Journal, 21*(1), 30-34. doi:10.5935/0946-5448.20170007

Khan, S., & Chang, R. (2013). Anatomy of the vestibular system: A review. *NeuroRehabilitation, 32*, 437-443. doi:10.3233/NRE-130866

Khatri, M., Raizada, R. M., & Puttewar, M. P. (2005). Epley's canalith-repositioning manoeuvre for benign paroxysmal positional vertigo. *Indian Journal of Otolaryngology and Head and Neck Surgery, 57*(4), 315-319.

Kim, E. J., Oh, S. Y., Kim, J. S., Yang, T. H., & Yang, S. Y. (2015). Persistent otolith dysfunction even after successful repositioning in benign paroxysmal positional vertigo. *Journal of the Neurological Sciences., 18*. doi:http://dx.doi.org/10.1016/j.jns.2015.09.012

Kim, H. J., & Kim, J. S. (2017). The Patterns of recurrences in idiopathic benign paroxysmal positional vertigo and self-treatment evaluation. *Frontiers in Neurology, 8*(690). doi:10.3389/fneur.2017.00690

Kim, H. J., Park, I., Lee, H. J., & Lee, O. (2016). The reliability and validity of gait speed with different walking pace and distances against general health, physical function, and chronic disease in aged adults. *Journal of Exercise Nutrition and Biochemistry, 20*(3), 46-50. doi:10.20463/jenb.2016.09.20.3.7

Kim, J. S., Oh, S. Y., Lee, S. H., Kang, J. H., Kim, D. U., Jeong, S. H., . . . Kim, H. J. (2012). Randomized clinical trial for geotropic horizontal canal benign paroxysmal positional vertigo. *Neurology, 79*(7), 700-707. doi:10.1212/WNL.0b013e3182648b8b

Kim, S. H., Jo, S. W., Chung, W. K., Byeon, H. K., & Lee, W. S. (2012). A cupulolith repositioning maneuver in the treatment of horizontal canal cupulolithiasis. *Auris, Nasus, Larynx, 39*(2), 163-168. doi:10.1016/j.anl.2011.03.008

Kim, T. H., & Kim, M. B. (2018). Effect of aging and direction of impulse in video head impulse test. *Laryngoscope, 128*(6), E228-E233. doi:10.1002/lary.26864

Kim, Y. K., Shin, J. E., & Chung, J. W. (2005). The effect of canalith repositioning for anterior semicircular canal canalithiasis. *ORL: Journal of Oto-Rhino-Laryngology and Its Related Specialties, 67*(1), 56-60. doi:10.1159/000084336

Kinne, B. L., Strace, C. L., & Crouch, N. A. (2012). The effectiveness of current interventions in the management of lateral canal benign paroxysmal positional

vertigo. *Physical Therapy Reviews, 17*(5), 292-300. doi:10.1179/1743288X12Y.0000000028

Kollén, L., Bjerlemo, B., & Möller, C. (2006). Evaluation of treatment in benign paroxysmal positional vertigo (BPPV). *Advances in Physiotherapy, 8*(3), 106-115. doi:10.1080/14038190600836866

Kollén, L., Frändin, K., Möller, M., Olsén, M., & Möller, C. (2012). Benign paroxysmal positional vertigo is a common cause of dizziness and unsteadiness in a large population of 75-year-olds. *Aging Clinical and Experimental Research, 24*(4), 317-323. doi:10.1007/BF03325263

Koo, J. W., Moon, I. J., Shim, W. S., Moon, S. Y., & Kim, J. S. (2006). Value of lying-down nystagmus in the lateralization of horizontal semicircular canal benign paroxysmal positional vertigo. *Otology & Neurotology, 27*(3), 367-371. doi:10.1097/00129492-200604000-00013

Korres, S., Balatsouras, D. G., & Ferekidis, E. (2006). Prognosis of patients with benign paroxysmal positional vertigo treated with repositioning manoeuvres. *Journal of Laryngology and Otology, 120*(7), 528-533. doi:http://dx.doi.org/10.1017/S0022215106000958

Korres, S., Riga, M. G., Xenellis, J., Korres, G. S., & Danielides, V. (2011). Treatment of the horizontal semicircular canal canalithiasis: pros and cons of the repositioning maneuvers in a clinical study and critical review of the literature. *Otology & Neurotology, 32*(8), 1302-1308. doi:10.1097/MAO.0b013e31822f0bc5

Lamb, S. E., Jørstad-Stein, E. C., Hauer, K., & Becker, C. (2005). Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus. *Journal of the American Geriatrics Society, 53*(9), 1618-1622. doi:10.1111/j.1532-5415.2005.53455.x

Lanca, S. M., Gazzola, J. M., Kasse, C. A., Branco-Barreiro, F. C. A., Vaz, D. P., & Scharlach, R. C. (2013). Body balance in elderly patients, 12 months after

treatment for BPPV. *Brazilian Journal of Otorhinolaryngology, 79*(1), 39-46. doi:http://dx.doi.org/10.5935/1808-8694.20130008

Laurent, G., Vereeck, L., Verbecque, E., Herssens, N., Casters, L., & Spildooren, J. (2021). Effect of age on treatment outcomes in benign paroxysmal positional vertigo: A systematic review. *Journal of the American Geriatrics Society (JAGS)*. doi:10.1111/jgs.17485

Lawson, J., Bamiou, D.-E., Cohen, H. S., & Newton, J. (2008). Positional vertigo in a falls service. *Age and Ageing, 37*(5), 585-588. doi:10.1093/ageing/afn151

Lee, H. J., Jeon, E. J., Lee, D. H., & Seo, J. H. (2020). Therapeutic efficacy of the Modified Epley Maneuver with a pillow under the shoulders. *Clinical and Experimental Otorhinolaryngology, 13*(4), 376-380. doi:10.21053/ceo.2019.01830

Lee, N. H., Kwon, H. J., & Ban, J. H. (2009). Analysis of residual symptoms after treatment in benign paroxysmal positional vertigo using questionnaire. *Otolaryngology - Head and Neck Surgery, 141*(2), 232-236. doi:http://dx.doi.org/10.1016/j.otohns.2009.04.006

Lee, S. H., Choi, K. D., Jeong, S. H., Oh, Y. M., Koo, J. W., & Kim, J. S. (2007). Nystagmus during neck flexion in the pitch plane in benign paroxysmal positional vertigo involving the horizontal canal. *Journal of the Neurological Sciences, 256*(1), 75-80. doi:https://doi.org/10.1016/j.jns.2007.02.026

Lee, S. H., & Kim, J. S. (2010). Benign paroxysmal positional vertigo. *Journal of Clinical Neurology (Korea), 6*(2), 51-63. doi:10.3988/jcn.2010.6.2.51

Legters, K., Whitney, S. L., Porter, R., & Buczek, F. (2005). The relationship between the Activities-specific Balance Confidence Scale and the Dynamic Gait Index in peripheral vestibular dysfunction. *Physiotherapy Research International, 10*(1), 10-22. doi:10.1002/pri.20

Lempert, T., & Tiel-Wilck, K. (1996). A positional maneuver for treatment of horizontal-canal benign positional vertigo. *Laryngoscope, 106*(4), 476-478. doi:10.1097/00005537-199604000-00015

Li, C., Layman, A. J., Carey, J. P., & Agrawal, Y. (2015). Epidemiology of vestibular evoked myogenic potentials: Data from the Baltimore Longitudinal Study of Aging. *Clinical Neurophysiology, 126*(11), 2207-2215. doi:10.1016/j.clinph.2015.01.008

Li, C., Layman, A. J., Geary, R., Anson, E., Carey, J. P., Ferrucci, L., & Agrawal, Y. (2015). Epidemiology of vestibulo-ocular reflex function: data from the Baltimore Longitudinal Study of Aging. *Otology & Neurotology, 36*(2), 267-272. doi:10.1097/MAO.0000000000000610

Li, J., & Li, H. (2010). New repositioning techniques for benign paroxysmal positional vertigo: The Li repositioning manoeuvres. *Journal of Laryngology and Otology, 124*(8), 905-908. doi:10.1017/S0022215109992520

Li, J., Tian, S., & Zou, S. (2017). Efficacy of the Li maneuver in treating posterior canal benign paroxysmal positional vertigo. *Acta Oto-Laryngologica, 137*(6), 588-592. doi:10.1080/00016489.2016.1258731

Li, J., Zou, S., & Tian, S. (2018). A prospective randomized controlled study of Li quick repositioning maneuver for geotropic horizontal canal BPPV. *Acta Oto-Laryngologica, 138*(9), 779-784. doi:10.1080/00016489.2018.1476778

Lim, K. B., & Lee, H. J. (2012). Computerized posturographic measurement in elderly women with unilateral knee osteoarthritis. *Annals of Rehabilitation Medicine, 36*(5), 618-626. doi:10.5535/arm.2012.36.5.618

Lindell, E., Kollén, L., Johansson, M., Karlsson, T., Rydén, L., Falk Erhag, H., . . . Finizia, C. (2020). Benign paroxysmal positional vertigo, dizziness, and health-related quality of life among older adults in a population-based setting. *European Archives of Oto-Rhino-Laryngology*. doi:10.1007/s00405-020-06357-1

Lindell, E., Kollén, L., Johansson, M., Karlsson, T., Rydén, L., Zettergren, A., . . . Finizia, C. (2020). Dizziness and its association with walking speed and falls efficacy among older men and women in an urban population. *Aging Clinical*

and Experimental Research, 32(6), 1049-1056. doi:10.1007/s40520-019-01303-6

Lopez-Escamez, J. A., Gamiz, M. J., Fernandez-Perez, A., & Gomez-Finana, M. (2005). Long-term outcome and health-related quality of life in benign paroxysmal positional vertigo. *European Archives of Oto-Rhino-Laryngology, 262*(6), 507-511. doi:http://dx.doi.org/10.1007/s00405-004-0841-x

Lopez-Escamez, J. A., Gomez Fiñana, M., Fernandez, A. J., Gámiz, M. J., & Sanchez-Canet, I. (2003). Impact of treatment on benign positional vertigo-related quality of life. *International Congress Series, 1240*, 1329-1332. doi:http://dx.doi.org/10.1016/S0531-5131(03)00693-9

Lopez, I., Honrubia, V., & Baloh, R. W. (1997). Aging and the human vestibular nucleus. *Journal of Vestibular Research, 7*, 77-85. doi:10.3233/VES-1997-7107

Lopez, I., Ishiyama, G., Tang, Y., Tokita, J., Baloh, R. W., & Ishiyama, A. (2005). Regional estimates of hair cells and supporting cells in the human crista ampullaris. *Journal of Neuroscience Research, 82*(3), 421-431. doi:10.1002/jnr.20652

Lowry, R. (1998-2018). Estimation of a sample's mean and variance from its median and range. Retrieved from http://vassarstats.net/median_range.html

Luryi, A. L., Wright, D., Lawrence, J., Babu, S., Larouere, M., Bojrab, D. I., . . . Schutt, C. A. (2018). Analysis of non-posterior canal benign paroxysmal positional vertigo in patients treated using the particle repositioning chair: A large, single-institution series. *American Journal of Otolaryngology--Head and Neck Medicine and Surgery, 39*(3), 313-316. doi:10.1016/j.amjoto.2018.03.019

Macambira, Y. K. d. S., Carnaúba, A. T. L., Fernandes, L. C. B. C., Bueno, N. B., & Menezes, P. d. L. (2017). Aging and wave-component latency delays in oVEMP and cVEMP: a systematic review with meta-analysis. *Brazilian*

Journal of Otorhinolaryngology, 83(4), 475-487. doi:https://doi.org/10.1016/j.bjorl.2016.12.006

MacDougall, H. G., Weber, K. P., McGarvie, L. A., Halmagyi, G. M., & Curthoys, I. S. (2009). The video head impulse test: diagnostic accuracy in peripheral vestibulopathy. *Neurology, 73*(14), 1134-1141. doi:10.1212/WNL.0b013e3181bacf85

Macias, J. D., Lambert, K. M., Massingale, S., Ellensohn, A., & Fritz, J. A. (2000). Variables affecting treatment in benign paroxysmal positional vertigo. *Laryngoscope, 110*(11), 1921-1924.

Male, A., Ramdharry, G., Davies, R. A., & Beith, I. D. (2018). A survey of current management of Benign Paroxysmal Positional Vertigo (BPPV) by physiotherapists' interested in vestibular rehabilitation in the UK. *Physiotherapy, 105*. doi:10.1016/j.physio.2018.08.007

Mantello, E., Paula, A., André, R., Moreno, N., Hyppolito, M., & Moriguti, J. (2011). Long-term efficacy of repositioning maneuvers in benign paroxysmal positional vertigo. *International Journal of Clinical Medicine, 02*. doi:10.4236/ijcm.2011.22029

Maranhao, E. T., & Maranhao Filho, P. (2015). Horizontal canal benign paroxysmal positional vertigo: diagnosis and treatment of 37 patients. *Arquivos de Neuro-Psiquiatria, 73*(6), 487-492. doi:10.1590/0004-282X20150040

Marchetti, G. F., Whitney, S. L., Blatt, P. J., Morris, L. O., & Vance, J. M. (2008). Temporal and spatial characteristics of gait during performance of the Dynamic Gait Index in people with and people without balance or vestibular disorders. *Physical Therapy, 88*(5), 640-651. doi:10.2522/ptj.20070130

Marchetti, G. F., Whitney, S. L., Redfern, M. S., & Furman, J. M. (2011). Factors associated with balance confidence in older adults with health conditions affecting the balance and vestibular System. *Archives of Physical Medicine and Rehabilitation, 92*(11), 1884-1891. doi:https://doi.org/10.1016/j.apmr.2011.06.015

Martellucci, S., Pagliuca, G., de Vincentiis, M., Greco, A., De Virgilio, A., Nobili Benedetti, F. M., . . . Gallo, A. (2016). Features of residual dizziness after canalith repositioning procedures for benign paroxysmal positional vertigo. *Otolaryngology-Head & Neck Surgery, 154*(4), 693-701. doi:10.1177/0194599815627624

Maslovara, S., Butkovic Soldo, S., Sestak, A., Milinkovic, K., Rogic-Namacinski, J., & Soldo, A. (2017). 25 (OH) D3 levels, incidence and recurrence of different clinical forms of BPPV. *Brazilian Journal of Otorhinolaryngology*. doi:10.1016/j.bjorl.2017.05.007

Maslovara, S., Soldo, S. B., Puksec, M., Balaban, B., & Penavic, I. P. (2012). Benign Paroxysmal Positional Vertigo (BPPV): Influence of pharmacotherapy and rehabilitation therapy on patients' recovery rate and life quality. *NeuroRehabilitation, 31*(4), 435-441. doi:http://dx.doi.org/10.3233/NRE-2012-00814

McClure, J. A. (1985). Horizontal canal BPV. *Journal of Otolaryngology, 14*(1), 30-35.

McCormack, H. M., Horne, D. J., & Sheather, S. (1988). Clinical applications of visual analogue scales: a critical review. *Psychological Medicine, 18*(4), 1007-1019. doi:10.1017/s0033291700009934

McGarvie, L. A., MacDougall, H. G., Halmagyi, G. M., Burgess, A. M., Weber, K. P., & Curthoys, I. S. (2015). The Video Head Impulse Test (vHIT) of semicircular canal function - Age-dependent normative values of VOR gain in healthy subjects. *Frontiers in Neurology, 6*, 154. doi:10.3389/fneur.2015.00154

MedCalc Statistical Software. (2018) (Version 18.10.2). Ostend, Belgium: MedCalc Software bvba. Retrieved from http://www.medcalc.org

Meli, A., Zimatore, G., Badaracco, C., De Angelis, E., & Tufarelli, D. (2006). Vestibular rehabilitation and 6-month follow-up using objective and subjective measures. *Acta Oto-Laryngologica, 126*(3), 259-266. doi:10.1080/00016480500388885

Mendes, T., Maslovara, S., Vceva, A., & Soldo, S. B. (2017). Role of vestibular evoked myogenic potentials as an indicator of recovery in patients with benign paroxysmal positional vertigo. *Acta Clinica Croatica, 56*(4), 756-764. doi:http://dx.doi.org/10.20471/acc.2017.56.04.25

Merchant, S. N., Tsuji, K., Wall, C., Velázquez-Villaseñor, L., Glynn, R. J., & Rauch, S. D. (2000). Temporal bone studies of the human peripheral vestibular system: 1. Normative vestibular hair cell data. *Annals of Otology, Rhinology and Laryngology, 109*(5_suppl), 3-13. doi:10.1177/00034894001090S502

Meuli, L., & Dick, F. (2018). Understanding confounding in observational studies. *European Journal of Vascular and Endovascular Surgery, 55*(5), 737. doi:10.1016/j.ejvs.2018.02.028

Middleton, A., Fritz, S. L., & Lusardi, M. (2015). Walking speed: the functional vital sign. *Journal of Aging and Physical Activity, 23*(2), 314-322. doi:10.1123/japa.2013-0236

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ, 339*, b2535. doi:10.1136/bmj.b2535

Monobe, K. S. T. M. H. (2001). The outcome of the canalith repositioning procedure for benign paroxysmal positional vertigo: Are there any characteristic features of treatment failure cases? *Acta Oto-Laryngologica, 121*(545), 38-40. doi:10.1080/000164801750388081

Moon, S. Y., Kim, J. S., Kim, B. K., Kim, J. I., Lee, H., Son, S. I., . . . Lee, W. S. (2006). Clinical characteristics of benign paroxysmal positional vertigo in Korea: a multicenter study. *Journal of Korean Medical Science, 21*(3), 539-543. doi:10.3346/jkms.2006.21.3.539

Morimoto, H., Asai, Y., Johnson, E. G., Koide, Y., Niki, J., Sakai, S., . . . Wada, I. (2019). Objective measures of physical activity in patients with chronic unilateral vestibular hypofunction, and its relationship to handicap, anxiety and

postural stability. *Auris, Nasus, Larynx, 46*(1), 70-77. doi:10.1016/j.anl.2018.06.010

Morris, A. E., Lutman, M. E., & Yardley, L. (2009). Measuring outcome from vestibular rehabilitation, part II: refinement and validation of a new self-report measure. *International Journal of Audiology, 48*(1), 24-37. doi:10.1080/14992020802314905

Moser, A., & Korstjens, I. (2018). Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis. *European Journal of General Practice, 24*(1), 9-18. doi:10.1080/13814788.2017.1375091

Mossman, B., Mossman, S., Purdie, G., & Schneider, E. (2015). Age dependent normal horizontal VOR gain of head impulse test as measured with video-oculography. *Journal of otolaryngology - head & neck surgery = Le Journal d'oto-rhino-laryngologie et de chirurgie cervico-faciale, 44*(1), 29-29. doi:10.1186/s40463-015-0081-7

MSD Manual Professional Version. (2021). Epley maneuver: A simple treatment for a common cause of vertigo. Retrieved from https://www.msdmanuals.com/professional/multimedia/figure/ent_epley_maneuver

Mueller, M., Strobl, R., Jahn, K., Linkohr, B., Ladwig, K. H., Mielck, A., & Grill, E. (2014). Impact of vertigo and dizziness on self-perceived participation and autonomy in older adults: results from the KORA-Age study. *Quality of Life Research, 23*(8), 2301-2308. doi:10.1007/s11136-014-0684-x

Mui, A. C. (1996). Geriatric Depression Scale as a community screening instrument for elderly Chinese immigrants. *International Psychogeriatrics, 8*(3), 445-458. doi:10.1017/S1041610296002803

Mujeeb, M., & Khan, N. (2000). Epley's manoeuvre: treatment of choice for benign paroxysmal positional vertigo. *Journal of Laryngology and Otology, 114*(11), 844-847.

Naber, C. M., Water-Schmeder, O., Bohrer, P. S., Matonak, K., Bernstein, A. L., & Merchant, M. A. (2011). Interdisciplinary treatment for vestibular dysfunction: the effectiveness of mindfulness, cognitive-behavioral techniques, and vestibular rehabilitation. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery, 145*(1), 117-124. doi:10.1177/0194599811399371

Nemmers, T. M., & Miller, J. W. (2008). Factors influencing balance in healthy community-dwelling women age 60 and older. *Journal of Geriatric Physical Therapy, 31*(3), 93-100. doi:10.1519/00139143-200831030-00003

Ng, S. S., Ng, P. C., Lee, C. Y., Ng, E. S., Tong, M. H., Fong, S. S., & Tsang, W. W. (2013). Assessing the walking speed of older adults: the influence of walkway length. *American Journal of Physical Medicine and Rehabilitation, 92*(9), 776-780. doi:10.1097/PHM.0b013e31828769d0

Ntoumanis, N. (2014). Analysing longitudinal data with multilevel modelling. *The European Health Psychologist, 16*, 40-45.

Nunez, R. A., Cass, S. P., & Furman, J. M. (2000). Short- and long-term outcomes of canalith repositioning for benign paroxysmal positional vertigo. *Otolaryngology-Head and Neck Surgery, 122*(5), 647-653. doi:10.1016/s0194-5998(00)70190-2

Nuti, D., Agus, G., Barbieri, M. T., & Passali, D. (1998). The management of horizontal-canal paroxysmal positional vertigo. *Acta Oto-Laryngologica, 118*(4), 455-460. doi:10.1080/00016489850154559

Nyenhuis, D. L., Yamamoto, C., Luchetta, T., Terrien, A., & Parmentier, A. (1999). Adult and geriatric normative data and validation of the profile of mood states. *Journal of Clinical Psychology, 55*(1), 79-86. doi:10.1002/(sici)1097-4679(199901)55:1<79::aid-jclp8>3.0.co;2-7

Nyunt, M. S., Fones, C., Niti, M., & Ng, T. P. (2009). Criterion-based validity and reliability of the Geriatric Depression Screening Scale (GDS-15) in a large

validation sample of community-living Asian older adults. *Aging & Mental Health, 13*(3), 376-382. doi:10.1080/13607860902861027

Oghalai, J. S., Manolidis, S., Barth, J. L., Stewart, M. G., & Jenkins, H. A. (2000). Unrecognized benign paroxysmal positional vertigo in elderly patients. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery, 122*(5), 630-634. doi:10.1067/mhn.2000.105415

Oliva Domínguez, M., Bartual Magro, J., Dañino González, J. L., Dañino González, G., Roquette Gaona, J., & Bartual Pastor, J. (2005). Postural control related to age in patients with benign positional paroxysmal vertigo. *Acta Otorrinolaringologica Espanola, 56*(8), 354-360.

Olsson Moller, U., Hansson, E. E., Ekdahl, C., Midlov, P., Jakobsson, U., & Kristensson, J. (2014). Fighting for control in an unpredictable life - a qualitative study of older persons' experiences of living with chronic dizziness. *BMC Geriatrics, 14*, 97. doi:10.1186/1471-2318-14-97

Oron, Y., Cohen-Atsmoni, S., Len, A., & Roth, Y. (2015). Treatment of horizontal canal BPPV: pathophysiology, available maneuvers, and recommended treatment. *Laryngoscope, 125*(8), 1959-1964. doi:http://dx.doi.org/10.1002/lary.25138

Ouchterlony, D., Masanic, C., Michalak, A., Topolovec-Vranic, J., & Rutka, J. A. (2016). Treating benign paroxysmal positional vertigo in the patient with traumatic brain injury: Effectiveness of the canalith repositioning procedure. *Journal of Neuroscience Nursing, 48*(2), 90-99; quiz E91. doi:10.1097/JNN.0000000000000186

Ozdilek, A., Yalinay Dikmen, P., Acar, E., Ayanoglu Aksoy, E., & Korkut, N. (2019). Determination of anxiety, health anxiety and somatosensory amplification levels in individuals with benign paroxysmal positional vertigo. *The Journal of International Advanced Otology, 15*(3), 436-441. doi:http://dx.doi.org/10.5152/iao.2019.6874

Pachana, N. A., Byrne, G. J., Siddle, H., Koloski, N., Harley, E., & Arnold, E. (2007). Development and validation of the Geriatric Anxiety Inventory. *International Psychogeriatrics, 19*(1), 103-114. doi:10.1017/s1041610206003504

Papathanasiou, E. S., Murofushi, T., Akin, F. W., & Colebatch, J. G. (2014). International guidelines for the clinical application of cervical vestibular evoked myogenic potentials: An expert consensus report. *Clinical Neurophysiology, 125*(4), 658-666. doi:10.1016/j.clinph.2013.11.042

Park, H., & Jung, T. (2018). Limits of stability, tandem walk, and adaptation test in individuals with symptomatic knee osteoarthritis: A case-control comparison with knee OA and healthy knee controls. *International Journal of Human Movement and Sports Sciences, 6*(2), 23-29. doi:10.13189/saj.2018.060201

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

Parnes, L. S., & McClure, J. A. (1992). Free-floating endolymph particles: a new operative finding during posterior semicircular canal occlusion. *Laryngoscope, 102*(9), 988-992. doi:10.1288/00005537-199209000-00006

Parnes, L. S., & Nabi, S. (2009). The diagnosis and management of benign paroxysmal positional vertigo. *Seminars in Hearing, 30*(4), 287-305. doi:http://dx.doi.org/10.1055/s-0029-1241129

Payette, M. C., Belanger, C., Leveille, V., & Grenier, S. (2016). Fall-related psychological concerns and anxiety among community-dwelling older adults: Systematic review and meta-analysis. *PloS One, 11*(4), e0152848. doi:10.1371/journal.pone.0152848

Pedalini, M. E. B., Cruz, O. L. M., Bittar, R. S. M., Lorenzi, M. C., & Grasel, S. S. (2009). Sensory organization test in elderly patients with and without vestibular dysfunction. *Acta Oto-Laryngologica, 129*(9), 962-965. doi:10.1080/00016480802468930

Peluso, É. T. P., Quintana, M. I., & Ganança, F. F. (2016). Anxiety and depressive disorders in elderly with chronic dizziness of vestibular origin. *Brazilian Journal of Otorhinolaryngology, 82*(2), 209-214. doi:https://doi.org/10.1016/j.bjorl.2015.04.015

Perera, S., Mody, S. H., Woodman, R. C., & Studenski, S. A. (2006). Meaningful change and responsiveness in common physical performance measures in older adults. *Journal of the American Geriatrics Society, 54*(5), 743-749. doi:10.1111/j.1532-5415.2006.00701.x

Pérez-Vázquez, P., & Franco-Gutiérrez, V. (2017). Treatment of benign paroxysmal positional vertigo. A clinical review. *Journal of Otology, 12*(4), 165-173. doi:https://doi.org/10.1016/j.joto.2017.08.004

Pérez, P., Franco, V., Cuesta, P., Aldama, P., Alvarez, M. J., & Méndez, J. C. (2012). Recurrence of benign paroxysmal positional vertigo. *Otology and Neurotology, 33*(3), 437-443. doi:10.1097/MAO.0b013e3182487f78

Peterka, R. J., & Black, F. O. (1990). Age-related changes in human posture control: sensory organization tests. *Journal of Vestibular Research, 1*(1), 73-85.

Piker, E. G., & Jacobson, G. P. (2014). Self-report symptoms differ between younger and older dizzy patients. *Otology & Neurotology, 35*(5), 873-879. doi:10.1097/mao.0000000000000391

Plodpai, Y., Atchariyasathian, V., & Khaimook, W. (2014). The characteristic differences of benign paroxysmal positional vertigo among the elderly and the younger patients: A 10-year retrospective review. *Journal of the Medical Association of Thailand, 97*(8), 850-855.

Polensek, S. H., Sterk, C. E., & Tusa, R. J. (2008). Screening for vestibular disorders: a study of clinicians' compliance with recommended practices. *Medical Science Monitor, 14*(5), Cr238-242.

Pollak, L. (2009). The importance of repeated clinical examination in patients with suspected benign paroxysmal positional vertigo. *Otology and Neurotology, 30*(3), 356-358. doi:10.1097/MAO.0b013e3181967b9c

Pollak, L., Klein, C., Rafael, S., Vera, K., & Rabey, J. M. (2003). Anxiety in the first attack of vertigo. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery, 128*(6), 829-834. doi:10.1016/s0194-5998(03)00454-6

Pollak, L., Kushnir, M., & Goldberg, H. S. (2011). Physical inactivity as a contributing factor for onset of idiopathic benign paroxysmal positional vertigo. *Acta Oto-Laryngologica, 131*(6), 624-627. doi:10.3109/00016489.2011.552524

Pollak, L., Kushnir, M., Shpirer, Y., Zomer, Y., & Flechter, S. (2005). Approach to benign paroxysmal positional vertigo in old age. *Israel Medical Association Journal, 7*(7), 447-450.

Pollak, L., Segal, P., Stryjer, R., & Stern, H. G. (2012). Beliefs and emotional reactions in patients with benign paroxysmal positional vertigo: a longitudinal study. *American Journal of Otolaryngology, 33*(2), 221-225. doi:10.1016/j.amjoto.2011.07.002

Powell, L. E., & Myers, A. M. (1995). The Activities-specific Balance Confidence (ABC) Scale. *Journals of Gerontology. Series A: Biological Sciences and Medical Sciences, 50A*(1), M28-34. doi:10.1093/gerona/50a.1.m28

Prim-Espada, M. P., De Diego-Sastre, J. I., & Perez-Fernandez, E. (2010). Meta-analysis on the efficacy of Epley's manoeuvre in benign paroxysmal positional vertigo. *Neurologia, 25*(5), 295-299. doi:http://dx.doi.org/10.1016/j.nrl.2010.01.004

Prokopakis, E., Vlastos, I. M., Tsagournisakis, M., Christodoulou, P., Kawauchi, H., & Velegrakis, G. (2013). Canalith repositioning procedures among 965 patients with benign paroxysmal positional vertigo. *Audiology and Neurotology, 18*(2), 83-88. doi:http://dx.doi.org/10.1159/000343579

Prokopakis, E. P., Chimona, T., Tsagournisakis, M., Christodoulou, P., Hirsch, B. E., Lachanas, V. A., . . . Velegrakis, G. A. (2005). Benign paroxysmal positional vertigo: 10-Year experience in treating 592 patients with canalith repositioning

procedure. *Laryngoscope, 115*(9), 1667-1671. doi:http://dx.doi.org/10.1097/01.mlg.0000175062.36144.b9

Rashad, U. M. (2009). Long-term follow up after Epley's manoeuvre in patients with benign paroxysmal positional vertigo. *Journal of Laryngology and Otology, 123*(1), 69-74. doi:10.1017/S0022215108002430

Reinink, H., Wegner, I., Stegeman, I., & Grolman, W. (2014). Rapid systematic review of repeated application of the Epley maneuver for treating posterior BPPV. *Otolaryngology - Head and Neck Surgery (United States), 151*(3), 399-406. doi:http://dx.doi.org/10.1177/0194599814536530

Review Manager (RevMan) [Computer program]. (2014) (Version 5.3). Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration. Retrieved from https://training.cochrane.org/online-learning/core-software-cochrane-reviews/revman/revman-5-download

Ribeiro, K. F., Oliveira, B. S., Freitas, R. V., Ferreira, L. M., Deshpande, N., & Guerra, R. O. (2017). Effectiveness of otolith repositioning maneuvers and vestibular rehabilitation exercises in elderly people with benign paroxysmal positional vertigo: A systematic review. *Brazilian Journal of Otorhinolaryngology*. doi:10.1016/j.bjorl.2017.06.003

Ribeiro, K. M., Ferreira, L. M., Freitas, R. V., Silva, C. N., Deshpande, N., & Guerra, R. O. (2016). "Positive to Negative" Dix-Hallpike test and benign paroxysmal positional vertigo recurrence in elderly undergoing canalith repositioning maneuver and vestibular rehabilitation. *International Archives of Otorhinolaryngology, 20*(4), 344-352. doi:10.1055/s-0036-1572528

Ribeiro, K. M., Freitas, R. V., Ferreira, L. M., Deshpande, N., & Guerra, R. O. (2017). Effects of balance vestibular rehabilitation therapy in elderly with benign paroxysmal positional vertigo: A randomized controlled trial. *Disability and Rehabilitation, 39*(12), 1198-1206. doi:10.1080/09638288.2016.1190870

Richard, W., Bruintjes, T. D., Oostenbrink, P., & Leeuwen, R. B. (2005). Efficacy of the Epley maneuver for posterior canal BPPV: A long-term, controlled study of 81 patients. *Ear, Nose, and Throat Journal, 84*(1), 22-25.

Richter, E. (1980). Quantitative study of human scarpa's ganglion and vestibular sensory epithelia. *Acta Oto-Laryngologica, 90*(1-6), 199-208. doi:10.3109/00016488009131716

Riga, M., Bibas, A., Xenellis, J., & Korres, S. (2011). Inner ear disease and benign paroxysmal positional vertigo: A critical review of incidence, linical haracteristics, and management. *International Journal of Otolaryngology, 2011*, 709469. doi:10.1155/2011/709469

Riga, M., Korres, S., Korres, G., & Danielides, V. (2013). Apogeotropic variant of lateral semicircular canal benign paroxysmal positional vertigo: is there a correlation between clinical findings, underlying pathophysiologic mechanisms and the effectiveness of repositioning maneuvers? *Otology & Neurotology, 34*(6), 1155-1164. doi:10.1097/MAO.0b013e318280db3a

Robertson, M. C., Campbell, A. J., & Herbison, P. (2005). Statistical analysis of efficacy in falls prevention trials. *The Journals of Gerontology: Series A, 60*(4), 530-534. doi:10.1093/gerona/60.4.530

Rodrigues, D. L., Ledesma, A. L. L., de Oliveira, C. A. P., & Bahamad Junior, F. (2018). Physical therapy for posterior and horizontal canal benign paroxysmal positional vertigo: Long-term Effect and Recurrence: A systematic review. *International Archives of Otorhinolaryngology, 22*(4), 455-459. doi:10.1055/s-0037-1604345

Rosengren, S. M., Govender, S., & Colebatch, J. G. (2011). Ocular and cervical vestibular evoked myogenic potentials produced by air- and bone-conducted stimuli: Comparative properties and effects of age. *Clinical Neurophysiology, 122*(11), 2282-2289. doi:10.1016/j.clinph.2011.04.001

Rosenhall, U. (1973). Degenerative patterns in the aging human vestibular neuro-epithelia. *Acta Oto-Laryngologica, 76*(1-6), 208-220. doi:10.3109/00016487309121501

Ross, M. D., Peacor, D., Johnsson, L. G., & Allard, L. F. (1976). Observations on normal and degenerating human otoconia. *Annals of Otology, Rhinology and Laryngology, 85*(3 pt 1), 310-326. doi:10.1177/000348947608500302

Rubin, D. B. (1987). *Multiple imputation for nonresponse in surveys*: Wiley.

Sachdeva, K., & Sao, T. (2020). The clinical response time of Epley maneuvers for treatment of BPPV: A hospital based study. *Indian journal of otolaryngology, and head, and neck surgery, 72*(4), 503-507. doi:10.1007/s12070-020-02038-x

Sakaida, M., Takeuchi, K., Ishinaga, H., Adachi, M., & Majima, Y. (2003). Long-term outcome of benign paroxysmal positional vertigo. *Neurology, 60*(9), 1532-1534. doi:10.1212/01.wnl.0000061477.03862.4d

Salvinelli, F., Trivelli, M., Casale, M., Firrisi, L., Di Peco, V., D'Ascanio, L., . . . Bernabei, R. (2004). Treatment of benign positional vertigo in the elderly: A randomized trial. *Laryngoscope, 114*(5), 827-831. doi:http://dx.doi.org/10.1097/00005537-200405000-00007

Sato, G., Sekine, K., Matsuda, K., & Takeda, N. (2013). Risk factors for poor outcome of a single Epley maneuver and residual positional vertigo in patients with benign paroxysmal positional vertigo. *Acta Oto-Laryngologica, 133*(11), 1124-1127. doi:http://dx.doi.org/10.3109/00016489.2013.817681

Schmidheiny, A., Swanenburg, J., Straumann, D., de Bruin, E. D., & Knols, R. H. (2015). Discriminant validity and test re-test reproducibility of a gait assessment in patients with vestibular dysfunction. *BMC Ear, Nose, and Throat Disorders, 15*, 6. doi:10.1186/s12901-015-0019-8

Schober, P., & Vetter, T. R. (2018). Repeated measures designs and analysis of longitudinal data: If at first you do not succeed - try, try again. *Anesthesia and Analgesia, 127*(2), 569-575. doi:10.1213/ANE.0000000000003511

Schuknecht, H. F. (1969). Cupulolithiasis. *Archives of Otolaryngology, 90*(6), 765-778. doi:10.1001/archotol.1969.00770030767020

Sekine, K., Imai, T., Sato, G., Ito, M., & Takeda, N. (2006). Natural history of benign paroxysmal positional vertigo and efficacy of Epley and Lempert maneuvers. *Otolaryngology - Head and Neck Surgery, 135*(4), 529-533. doi:http://dx.doi.org/10.1016/j.otohns.2005.09.021

Semenov, Y. R., Bigelow, R. T., Xue, Q.-L., Lac, S. d., & Agrawal, Y. (2016). Association between vestibular and cognitive function in U.S. adults: Data from the National Health and Nutrition Examination Survey. *Journals of Gerontology. Series A: Biological Sciences and Medical Sciences, 71*(2), 243-250. doi:10.1093/gerona/glv069

Seo, T., Miyamoto, A., Saka, N., Shimano, K., & Sakagami, M. (2007). Immediate efficacy of the canalith repositioning procedure for the treatment of benign paroxysmal positional vertigo. *Otology and Neurotology, 28*(7), 917-919. doi:http://dx.doi.org/10.1097/MAO.0b013e3181468b6e

Seok, J. I., Lee, H. M., Yoo, J. H., & Lee, D. K. (2008). Residual dizziness after successful repositioning treatment in patients with benign paroxysmal positional vertigo. *Journal of Clinical Neurology (Seoul, Korea), 4*(3), 107. doi:10.3988/jcn.2008.4.3.107

Sherman, D., & Massoud, E. A. (2001). Treatment outcomes of benign paroxysmal positional vertigo. *The Journal of otolaryngology,* (5), 295-299. Retrieved from http://onlinelibrary.wiley.com/o/cochrane/clcentral/articles/333/CN-00733333/frame.html

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

Shumway-Cook, A., Taylor, C. S., Matsuda, P. N., Studer, M. T., & Whetten, B. K. (2013). Expanding the scoring system for the Dynamic Gait Index. *Physical Therapy, 93*(11), 1493-1506. doi:10.2522/ptj.20130035

Shumway-Cook, A., & Woollacott, M. H. (1995). *Motor control : theory and practical applications*. Baltimore: Williams & Wilkins.

Silva, C. N., Ribeiro, K. M., Freitas, R. V., Ferreira, L. M., & Guerra, R. O. (2016). Vertiginous symptoms and objective measures of postural balance in elderly people with benign paroxysmal positional vertigo submitted to the Epley maneuver. *International Archives of Otorhinolaryngology, 20*(1), 61-68. doi:10.1055/s-0035-1565915

Sim, E., Tan, D., & Hill, K. (2019). Poor treatment outcomes following repositioning maneuvers in younger and older adults with benign paroxysmal positional vertigo: A systematic review and meta-analysis. *Journal of the American Medical Directors Association, 20*(2), 224.e221-224.e223. doi:https://doi.org/10.1016/j.jamda.2018.11.019

Singh, H., Sanders, O., McCombe Waller, S., Bair, W. N., Beamer, B., Creath, R. A., & Rogers, M. W. (2017). Relationship between head-turn gait speed and lateral balance function in community-dwelling older adults. *Archives of Physical Medicine and Rehabilitation, 98*(10), 1955-1961. doi:10.1016/j.apmr.2017.05.006

Sloane, P. D., Baloh, R. W., & Honrubia, V. (1989). The vestibular system in the elderly: Clinical implications. *American Journal of Otolaryngology, 10*(6), 422-429. doi:10.1016/0196-0709(89)90038-0

Smouha, E. (2013). Inner ear disorders. *NeuroRehabilitation, 32*, 455-462. doi:10.3233/NRE-130868

Sridhar, S., Panda, N., & Raghunathan, M. (2003). Efficacy of particle repositioning maneuver in BPPV: A prospective study. *American Journal of Otolaryngology - Head and Neck Medicine and Surgery, 24*(6), 355-360. doi:http://dx.doi.org/10.1016/S0196-0709%2803%2900069-3

Staab, J. P., & Ruckenstein, M. J. (2003). Which comes first? Psychogenic dizziness versus otogenic anxiety. *Laryngoscope, 113*(10), 1714-1718. doi:10.1097/00005537-200310000-00010

Stam, H., Wisse, M., Mulder, B., van der Wouden, J. C., Maarsingh, O. R., & van der Horst, H. E. (2016). Dizziness in older people: at risk of shared therapeutic nihilism between patient and physician. A qualitative study. *BMC Family Practice, 17*, 74. doi:10.1186/s12875-016-0474-3

Stambolieva, K., & Angov, G. (2006). Postural stability in patients with different durations of benign paroxysmal positional vertigo. *European Archives of Oto-Rhino-Laryngology, 263*(2), 118-122. doi:http://dx.doi.org/10.1007/s00405-005-0971-9

Sunderland, M., Newby, J. M., & Andrews, G. (2013). Health anxiety in Australia: prevalence, comorbidity, disability and service use. *British Journal of Psychiatry, 202*(1), 56-61. doi:10.1192/bjp.bp.111.103960

Tan, F. E. S., Jolani, S., & Verbeek, H. (2018). Guidelines for multiple imputations in repeated measurements with time-dependent covariates: A case study. *Journal of Clinical Epidemiology, 102*, 107-114. doi:10.1016/j.jclinepi.2018.06.006

Tan, J., Deng, Y., Zhang, T., & Wang, M. (2017). Clinical characteristics and treatment outcomes for benign paroxysmal positional vertigo comorbid with hypertension. *Acta Oto-Laryngologica, 137*(5), 482-484. doi:10.1080/00016489.2016.1247985

Teggi, R., Giordano, L., Bondi, S., Fabiano, B., & Bussi, M. (2011). Residual dizziness after successful repositioning maneuvers for idiopathic benign paroxysmal positional vertigo in the elderly. *European Archives of Oto-Rhino-Laryngology, 268*(4), 507-511. doi:http://dx.doi.org/10.1007/s00405-010-1422-9

Teggi, R., & Nuti, D. (2017). Residual dizziness after physical treatment for benign paroxysmal positional Vertigo. A review of recent literature. *EC Neurology, 7*(4), 158-164.

Teggi, R., Quaglieri, S., Gatti, O., Benazzo, M., & Bussi, M. (2013). Residual dizziness after successful repositioning maneuvers for idiopathic benign

paroxysmal positional vertigo. *ORL: Journal of Oto-Rhino-Laryngology and Its Related Specialties, 75*(2), 74-81. doi:10.1159/000350255

Teixeira, L. J., & Machado, J. N. (2006). Maneuvers for the treatment of benign positional paroxysmal vertigo: a systematic review. *Brazilian Journal of Otorhinolaryngology, 72*(1), 130-139. doi:10.1016/s1808-8694(15)30046-x

The Joanna Briggs Institute. (2014). *Joanna Briggs Institute Reviewers' Manual: 2014 edition*: The Joanna Briggs Institute.

Therrien, Z., & Hunsley, J. (2012). Assessment of anxiety in older adults: a systematic review of commonly used measures. *Aging & Mental Health, 16*(1), 1-16. doi:10.1080/13607863.2011.602960

Tirelli, G., Nicastro, L., Gatto, A., & Tofanelli, M. (2017). Repeated canalith repositioning procedure in BPPV: Effects on recurrence and dizziness prevention. *American Journal of Otolaryngology - Head and Neck Medicine and Surgery, 38*(1), 38-43. doi:http://dx.doi.org/10.1016/j.amjoto.2016.09.009

Tirelli, G., & Russolo, M. (2004). 360-Degree canalith repositioning procedure for the horizontal canal. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery, 131*(5), 740-746. doi:10.1016/j.otohns.2004.01.021

Toupet, M., Ferrary, E., & Bozorg Grayeli, A. (2012). Effect of repositioning maneuver type and postmaneuver restrictions on vertigo and dizziness in benign positional paroxysmal vertigo. *ScientificWorldJournal, 2012*, 162123-162127. doi:10.1100/2012/162123

Toupet, M., Ferrary, E., & Grayeli, A. B. (2011). Visual analog scale to assess vertigo and dizziness after repositioning maneuvers for benign paroxysmal positional vertigo. *Journal of Vestibular Research: Equilibrium and Orientation, 21*(4), 235-241. doi:http://dx.doi.org/10.3233/VES-2011-0420

Tuunainen, E., Poe, D., Jäntti, P., Varpa, K., Rasku, J., Toppila, E., & Pyykkö, I. (2011). Presbyequilibrium in the oldest old, a combination of vestibular,

oculomotor and postural deficits. *Aging Clinical and Experimental Research, 23*(5), 364-371. doi:10.1007/BF03337761

Uz, U., Uz, D., Akdal, G., & Celik, O. (2019). Efficacy of Epley maneuver on quality of Life of elderly patients with subjective BPPV. *Journal of International Advanced Otology, 15*(3), 420-424. doi:10.5152/iao.2019.6483

Vaduva, C., Esteban-Sanchez, J., Sanz-Fernandez, R., & Martin-Sanz, E. (2018). Prevalence and management of post-BPPV residual symptoms. *European Archives of Oto-Rhino-Laryngology, 275*(6), 1429-1437. doi:10.1007/s00405-018-4980-x

van den Broek, E. M., van der Zaag-Loonen, H. J., & Bruintjes, T. D. (2014). Systematic review: Efficacy of Gufoni maneuver for treatment of lateral canal benign paroxysmal positional vertigo with geotropic nystagmus. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery, 150*(6), 933-938. doi:10.1177/0194599814525919

Van Der Scheer-Horst, E. S., Van Benthem, P. P. G., Bruintjes, T. D., Van Leeuwen, R. B., & Van Der Zaag-Loonen, H. J. (2014). The efficacy of vestibular rehabilitation in patients with benign paroxysmal positional vertigo: A rapid review. *Otolaryngology - Head and Neck Surgery (United States), 151*(5), 740-745. doi:http://dx.doi.org/10.1177/0194599814546479

van Leeuwen, R. B., & Bruintjes, T. D. (2014). Dizziness in the elderly: diagnosing its causes in a multidisciplinary dizziness unit. *Ear, Nose, and Throat Journal, 93*(4-5), 162, 164, 166-167.

van Vugt, V. A., Diaz Nerio, P. M., van der Wouden, J. C., van der Horst, H. E., & Maarsingh, O. R. (2017). Use of canalith repositioning manoeuvres and vestibular rehabilitation: a GP survey. *Scandinavian Journal of Primary Health Care, 35*(1), 19-26. doi:10.1080/02813432.2017.1288683

Vannucchi, P., Asprella Libonati, G., & Gufoni, M. (2005). The physical treatment of lateral semicircular canal canalolithiasis. *Audiological Medicine, 3*(1), 52-56. doi:http://dx.doi.org/10.1080/16513860510029445

Vannucchi, P., Giannoni, B., & Pagnini, P. (1997). Treatment of horizontal semicircular canal benign paroxysmal positional vertigo. *Journal of Vestibular Research: Equilibrium and Orientation, 7*(1), 1-6.

Vannucchi, P., Pecci, R., & Giannoni, B. (2012). Posterior semicircular canal benign paroxysmal positional vertigo presenting with torsional downbeating nystagmus: an apogeotropic variant. *International Journal of Otolaryngology, 2012*, 413603. doi:10.1155/2012/413603

Vannucchi, P., Pecci, R., Giannoni, B., Di Giustino, F., Santimone, R., & Mengucci, A. (2015). Apogeotropic posterior semicircular canal benign paroxysmal positional vertigo: Some clinical and therapeutic considerations. *Audiology Research, 5*(1), 38-43. doi:http://dx.doi.org/10.4081/audiores.2015.130

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. *Brazilian Journal of Otorhinolaryngology, 79*(2), 150-157. doi:http://dx.doi.org/10.5935/1808-8694.20130027

Vereeck, L., Wuyts, F., Truijen, S., & Van de Heyning, P. (2008). Clinical assessment of balance: normative data, and gender and age effects. *International Journal of Audiology, 47*(2), 67-75. doi:10.1080/14992020701689688

Vibert, D., Kompis, M., & Häusler, R. (2003). Benign paroxysmal positional vertigo in older women may be related to osteoporosis and osteopenia. *Annals of Otology, Rhinology and Laryngology, 112*(10), 885-889. doi:10.1177/000348940311201010

von Brevern, M., Bertholon, P., Brandt, T., Fife, T., Imai, T., Nuti, D., & Newman-Toker, D. (2015). Benign paroxysmal positional vertigo: Diagnostic criteria.

Journal of Vestibular Research: Equilibrium and Orientation, 25(3-4), 105-117. doi:10.3233/ves-150553

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

von Brevern, M., Seelig, T., Neuhauser, H., & Lempert, T. (2004). Benign paroxysmal positional vertigo predominantly affects the right labyrinth. *Journal of Neurology, Neurosurgery and Psychiatry, 75*(10), 1487-1488. doi:10.1136/jnnp.2003.031500

Wallace, B., & Lifshitz, J. (2016). Traumatic brain injury and vestibulo-ocular function: current challenges and future prospects. *Eye Brain, 8*, 153-164. doi:10.2147/eb.S82670

Walther, L. E., Wenzel, A., Buder, J., Bloching, M. B., Kniep, R., & Blodow, A. (2013). Detection of human utricular otoconia degeneration in vital specimen and implications for benign paroxysmal positional vertigo. *European Archives of Oto-Rhino-Laryngology, 271*(12), 3133-3138. doi:10.1007/s00405-013-2784-6

Wang, Y., Xia, F., Wang, W., & Hu, W. (2018). Assessment of sleep quality in benign paroxysmal positional vertigo recurrence. *International Journal of Neuroscience, 128*, 1-22. doi:10.1080/00207454.2018.1486835

Watson, L. C., & Pignone, M. P. (2003). Screening accuracy for late-life depression in primary care: a systematic review. *Journal of Family Practice, 52*(12), 956-964.

Wegner, I., Niesten, M. E. F., Van Werkhoven, C. H., & Grolman, W. (2014). Rapid systematic review of the Epley maneuver versus vestibular rehabilitation for benign paroxysmal positional vertigo. *Otolaryngology - Head and Neck Surgery (United States), 151*(2), 201-207. doi:http://dx.doi.org/10.1177/0194599814534940

Wei, W., Sayyid, Z. N., Ma, X., Wang, T., & Dong, Y. (2018). Presence of anxiety and depression symptoms affects the first time treatment efficacy and recurrence of benign paroxysmal positional vertigo. *Frontiers in Neurology, 9*(178). doi:10.3389/fneur.2018.00178

Wetherell, J. L., Petkus, A. J., McChesney, K., Stein, M. B., Judd, P. H., Rockwell, E., . . . Patterson, T. L. (2009). Older adults are less accurate than younger adults at identifying symptoms of anxiety and depression. *The Journal of nervous and mental disease, 197*(8), 623-626. doi:10.1097/NMD.0b013e3181b0c081

Whitney, S., Wrisley, D., & Furman, J. (2003). Concurrent validity of the Berg Balance Scale and the Dynamic Gait Index in people with vestibular dysfunction. *Physiotherapy Research International, 8*(4), 178-186. doi:10.1002/pri.288

Whitney, S. L., Hudak, M. T., & Marchetti, G. F. (1999). The Activities-specific Balance Confidence Scale and the Dizziness Handicap Inventory: A comparison. *Journal of Vestibular Research, 9*(4), 253-259.

Whitney, S. L., Marchetti, G. F., & Morris, L. O. (2005). Usefulness of the Dizziness Handicap Inventory in the screening for benign paroxysmal positional vertigo. *Otology & Neurotology, 26*(5), 1027-1033. doi:10.1097/01.mao.0000185066.04834.4e

Woodworth, B. A., Gillespie, M. B., & Lambert, P. R. (2004). The canalith repositioning procedure for benign positional vertigo: A meta-analysis. *The Laryngoscope, 114*(7), 1143-1146. doi:10.1097/00005537-200407000-00002

Wrisley, D. M., Walker, M. L., Echternach, J. L., & Strasnick, B. (2003). Reliability of the dynamic gait index in people with vestibular disorders. *Archives of Physical Medicine and Rehabilitation, 84*(10), 1528-1533. doi:10.1016/S0003-9993(03)00274-0

Yacovino, D. A., Hain, T. C., & Gualtieri, F. (2009). New therapeutic maneuver for anterior canal benign paroxysmal positional vertigo. *Journal of Neurology, 256*(11), 1851-1855. doi:10.1007/s00415-009-5208-1

Yardley, L. (2004). Fear of falling: links between imbalance and anxiety. *Reviews in Clinical Gerontology, 13*(3), 195-201. doi:10.1017/S0959259803001023

Yeo, S. C., Ahn, S. K., Lee, H. J., Cho, H. J., Kim, S. W., Woo, S. H., . . . Park, J. J. (2018). Idiopathic benign paroxysmal positional vertigo in the elderly: a long-term follow-up study. *Aging Clinical and Experimental Research, 30*(2), 153-159. doi:10.1007/s40520-017-0763-2

Yesavage, J. A., & Sheikh, J. I. (1986). 9/Geriatric Depression Scale (GDS). *Clinical Gerontologist, 5*(1-2), 165-173. doi:10.1300/J018v05n01_09

Yimtae, K., Srirompotong, S., & Sae-Seaw, P. (2003). A randomized trial of the canalith repositioning procedure. *Laryngoscope, 113*(5), 828-832. doi:http://dx.doi.org/10.1097/00005537-200305000-00011

Zalewski, C. K. (2015). Aging of the human vestibular system. *Seminars in hearing, 36*(3), 175-196. doi:10.1055/s-0035-1555120

Zhang, X., Qian, X., Lu, L., Chen, J., Liu, J., Lin, C., & Gao, X. (2017). Effects of Semont maneuver on benign paroxysmal positional vertigo: a meta-analysis. *Acta Oto-Laryngologica, 137*(1), 63-70. doi:10.1080/00016489.2016.1212265

Zhao, P., Li, J., Ding, Y., Wang, Y., & Zou, S. (2021). Li Maneuver for geotropic horizontal canal benign paroxysmal positional vertigo (HC-BPPV) -A better choice. *American Journal of Otolaryngology, 42*(5), 103132-103132. doi:10.1016/j.amjoto.2021.103132

Zhu, C. T., Zhao, X. Q., Ju, Y., Wang, Y., Chen, M. M., & Cui, Y. (2019). Clinical characteristics and risk factors for the recurrence of benign paroxysmal positional vertigo. *Frontiers in Neurology, 10*, 1190-1190. doi:10.3389/fneur.2019.01190

Zuma e Maia, F. (2016). New treatment strategy for apogeotropic horizontal canal benign paroxysmal positional vertigo. *Audiology Research, 6*. doi:10.4081/audiores.2016.163

Appendices

Appendix A Poor Treatment Outcomes following Repositioning Manoeuvres in Younger and Older Adults with Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis

DOI: https://doi.org/10.1016/j.jamda.2018.11.019

JAMDA 20 (2019) 224.e1–224.e23

JAMDA

journal homepage: www.jamda.com

Review Article

Poor Treatment Outcomes Following Repositioning Maneuvers in Younger and Older Adults With Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis

Check for updates

Eyvonne Sim MAdvPhysioSci [a,*], Dawn Tan ClinDocPT [b,c], Keith Hill PhD [a]

[a] School of Physiotherapy and Exercise Science, Faculty of Health Sciences, Curtin University, Perth, Western Australia, Australia
[b] Physiotherapy Department, Singapore General Hospital, Singapore
[c] SIT Health & Social Sciences Cluster, Singapore Institute of Technology, Singapore

Keywords:
Benign paroxysmal positional vertigo
repositioning maneuvers
treatment outcomes
residual dizziness
recurrence
older and younger adults

ABSTRACT

Objective: This systematic review aimed to methodically review the available evidence on poor treatment outcomes after repositioning maneuver treatments in adults with BPPV and whether there are differences in the outcomes for older and younger adults.
Data sources: Embase, CINAHL, Scopus, PsycINFO (Ovid), Central Register of Controlled Trials (CENTRAL), and PubMed.
Review methods: Studies were included if they were prospective experimental or observational studies with a minimal follow-up of 1 month; the subjects were at least 18 years old, had BPPV, and were treated with repositioning maneuvers. Studies were excluded if they were not available in English full text and if the outcomes used were confined to positional tests and subjective vertigo rating. Methodological quality was assessed using the Joanna Briggs Institute Critical Appraisal Checklists. Meta-analysis was performed to compare outcomes for younger and older (≥60 years) subjects where multiple studies utilized similar outcomes.
Results: Thirty-five studies were selected. The methodological quality was poor in more than 60% of the studies. Treatment efficacy, based on positional test results and symptom resolution and recurrence were the most common outcomes. Balance and quality of life measures improved after treatment but were not always normalized. Residual symptoms and psychoemotional consequences persisted in some subjects, despite BPPV resolution. Meta-analyses indicated poorer dynamic balance recovery and increased self-perceived level of handicap in the older group relative to the younger group.
Conclusions and Implications: Although repositioning maneuvers were effective in BPPV management, some patients experienced residual dizziness, postural instability, recurrences, and psychoemotional consequences at least 1 month after repositioning. Moreover, older adults experienced less improvements in dynamic balance and self-perceived handicap rating compared with younger people. These issues may further impact on older adults with BPPV physically and mentally and should be addressed by future better-quality research and interventions.

One of the most common peripheral vestibular conditions is benign paroxysmal positional vertigo (BPPV). BPPV is characterized by episodes of intense vertiginous giddiness, usually lasting less than a minute, triggered by specific head positions.[1] An epidemiologic study[2] reported a 1-year incidence rate of 0.6% and prevalence of 1.6%. The 1-year prevalence for adults older than 60 years old was 3.4% compared with 0.5% for those between 18 and 39 years old, and 1.7% for adults between 40 and 59 years old.[2]

Considerable research in BPPV has focused on exploring the treatment. Physical treatment for BPPV using repositioning maneuvers is well documented to be more efficacious, when compared with medications or no treatment.[3] Treatment efficacy of the Epley Maneuver was reported to be as high as 90% to 100% in the first 2 sessions.[4] Treatment efficacy for other maneuvers ranged from 60% to

The authors declare no conflicts of interest.
E. Sim is supported by the Curtin University Health Sciences Faculty International Research Scholarship for her ongoing PhD.
* Address correspondence to Eyvonne Sim, MAdvPhysioSci, Department of Physiotherapy, Singapore General Hospital, Outram Road, Singapore 169608, Singapore.
E-mail address: Eyvonne.Sim@gmail.com (E. Sim).

https://doi.org/10.1016/j.jamda.2018.11.019
1525-8610/

>90%.[5–7] Most of these studies focused primarily on treatment efficacy measured predominantly using positional tests and subjective self-report (symptom intensity/handicap). However, consideration of only these 2 outcome domains might not provide a complete picture of recovery. Poor treatment outcomes, such as balance impairment, dizziness, and anxiety, despite negative Dix-Hallpike test being achieved, have been reported in a small number of studies.[8–12] In addition, there remained a proportion of patients who did not respond favorably, or who had recurrence of symptoms after resolution of BPPV.[13,14] Several studies found that older adults, compared with younger adults, were more likely to experience such unfavorable outcomes,[15–17] whereas other studies did not find an age difference.[18–20]

The aim of this systematic review was to methodically review the current evidence on treatment outcomes after repositioning maneuvers in adults with BPPV to answer the following questions: (1) Are there poor short- and long-term outcomes seen in adults with BPPV following initial repositioning maneuvers, and what factors are associated with these poor outcomes? and (2) Do older adults with BPPV experience different outcomes compared with younger adults? To date, there have been no systematic reviews on poor treatment outcomes post repositioning maneuvers in younger and older adults with BPPV.

Methods

Poor outcomes were defined as any remaining vertigo, dizziness, unsteadiness, and/or suboptimal changes in objective assessments despite adequate repositioning maneuvers and BPPV resolution. Short and long term were defined as 1 and 6 months, respectively, from the initial repositioning treatment. For this systematic review, dizziness, vertigo, and unsteadiness were defined according to the International Classification of Vestibular Disorders I developed by the Committee for the Classification of Vestibular Disorders of the Bárány Society.[21] Dizziness was defined as "the sensation of disturbed or impaired spatial orientation without a false or distorted sense of motion" and is nonvertiginous in nature.[22] Vertigo was "the sensation of self-motion when no self-motion is occurring or the sensation of distorted self-motion during an otherwise normal head movement." It also included false sensations such as spinning, swaying, tilting, bobbing, bouncing, or sliding (nonspinning vertigo).[22]

Unsteadiness was defined as "the feeling of being unstable while seated, standing, or walking without a particular directional preference" and should decrease or be eliminated by added support such as holding onto a stable wall.[22] Balance impairment was defined as "reduced performance, when compared with normative data, on standardised assessment procedures to measure postural control." The assessment procedures might include simple clinical measures such as timed balance tests, functional gait and balance tests, posturography using the Neurocom Balance Master, or laboratory measures using force plates.

Searches were conducted using Embase, CINAHL, Scopus, PsycINFO (Ovid), Central Register of Controlled Trials (CENTRAL), and PubMed for papers published from 1997 to August 2018. The reference lists of retrieved relevant papers were also hand searched. The keywords used for searching the literature were formulated using the PICO strategy and adapted for the different databases. An example of the search strategy adapted for PubMed is outlined in Appendix Table 1.

The population included in this review was adults with BPPV aged 18 years and older. The diagnosis of BPPV must have been confirmed with positional tests. The focus treatment was the current office treatment using repositioning maneuvers (ie, nonsurgical and nonpharmaceutical treatments). These maneuvers included the Epley, the Semont, the Deep Head Hanging, the Lempert, and the Gufoni. Studies investigating medications, self-treatment, and vestibular rehabilitation were included if the interventions were studied in combination with the repositioning maneuvers. The rationale for these inclusion criteria for intervention type was that they are the commonly used treatment approaches for BPPV and have good research evidence of short term effectiveness.[23] Studies that included mainly participants with multiple-canal or bilateral BPPV or who reported dizziness/vertigo not related to BPPV were excluded. Only prospective experimental or observational studies in English were included. The studies needed to incorporate a minimum total follow-up period of 1 month. Included studies must have incorporated additional outcome measures, not including positional tests and self report dizziness measures.

After duplicates were removed, the studies were screened using title and abstract, after which potential studies were further assessed using full text. The final selection of articles was assessed for methodological quality using the Joanna Briggs Institute Critical Appraisal Checklists[24] by 2 independent reviewers. The team discussed and standardized the method of rating for the intention to treat and the control of other interventions criteria. The final score was based on the total number of criteria rated as "yes."

Data were extracted using standardized forms for participants in the repositioning maneuvers–only groups, with the consideration that the main effects were influenced only by such interventions. The only exception was recurrence, for which results were reported for any group with repositioning maneuvers. Where information was lacking, the authors were contacted by e-mail to request additional details.

For exploring the difference in outcomes between older and younger adults, we assigned the term "older adult population" to the studies with a mean/median age of 60 years and older. Studies were classified as having a "younger adult population" if they reported a mean/median sample age of less than 60 years. Data were synthesized using a narrative format with meta-analysis planned when appropriate. This systematic review was performed and reported in accordance with the PRISMA guidelines.[25]

Results

Study Selection

A total of 2205 studies were retrieved from the databases. After removal of duplicates and initial screen of titles and abstracts, 98 studies remained. Nine other studies were identified through hand searching. One hundred seven full texts were evaluated. Seventy-two studies were further excluded: 27 for not meeting follow-up criterion; 16 did not meet the outcomes criterion; 26 studies did not meet both criteria; 1 was a retrospective study and another 2 for treatment outside the scope defined for inclusion in the review. Thirty-five studies were included[9,10,26–58] (Figure 1).

Subject and Study Characteristics

There were 3834 participants (range 9-965) with BPPV in the included studies. The mean age of the participants ranged between 32 and 74 years in 29 studies. Three studies reported median ages >60 years.[26,27,56] Ten of 35 studies comprised subject populations with a mean/median age of ≥60 years,[26,27,30,35,42,47,48,55,56,58] including 4 on older adults only (aged 60 years and older).[26,27,30,47] There were 2113 female participants reported across 32 studies. Five studies included healthy controls as comparisons.[9,31,33,35,40]

There were 11 randomized controlled trials,[26–29,40,47,49–52,54] 23 quasi-experimental studies,[9,10,30–39,41–46,48,53,55–57] and 1 cohort study.[58] In all studies, the diagnosis of BPPV was confirmed with positive positional tests (Dix-Hallpike and roll tests). Eight studies had a follow-up time of 1 month,[9,28,30,32,39,49,51,54] whereas 9 had follow-up duration greater than 1 month to less than

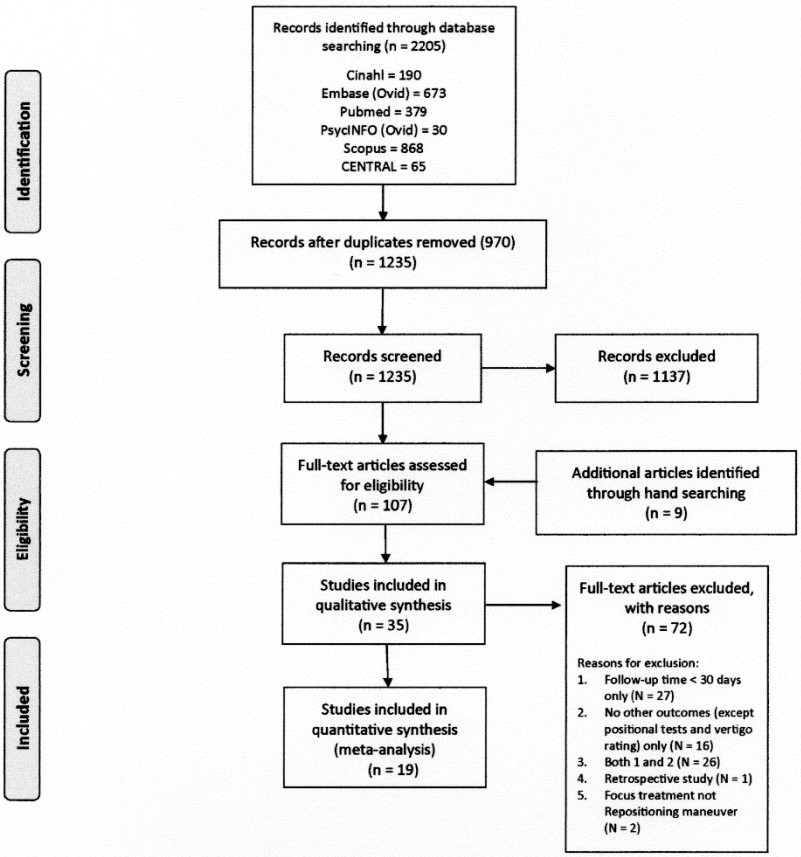


Fig. 1. PRISMA flow diagram for the screening process.

6 months.[10,26,27,31,35,40,43,48,57] The follow-up time for the remaining 18 studies were from 6 months to 5 years[29,33,34,36–38,41,42,44–47,50,52,53,55,56,58] (Table 1).

Intervention

The repositioning maneuvers used for treatment included Epley and Modified Epley Maneuvers, also known as Canalith Repositioning Maneuver (or Procedure),[26–34,36,38–46,48–57] the Semont or Liberatory Maneuver,[9,29,37,47] and the Lempert or Barbeque Maneuver.[33,44,45,49,57] Three studies did not specify the repositioning maneuvers used.[10,35,58]

Outcomes

Positional tests were widely used in the studies to determine treatment success. Subjective rating of dizziness/vertigo/recovery[27–29,34,36,37,43,49–51,54] and recurrence[26,36,41,42,44–47,50,52,53,55–58] were also commonly reported. The other outcomes used included the Dizziness Handicap Inventory,[10,27,32,40,43,54] the 36-item Short Form Survey (SF-36),[30,38–40,43] residual symptoms/time to remission of symptoms,[33,37,44,45,48,49] gait and balance measures,[9,27–29,31,37] dizziness frequency,[29] psychoemotional measures (anxiety, depression, self-perception),[10,33,40] the Vestibular Evoked Myogenic Potential,[35,56] self-report questionnaires on general health and level of disability,[37,47] vitamin D and calcium serum levels,[55] and sleep quality.[58]

Methodological quality

Of the 11 randomized controlled trials, only 4 scored 7 and higher, out of a total possible 13 points.[26–28,52] The scores ranged from 3/13 to 8/13, with a median score of 6/13. None of the randomized controlled trials were rated as having blinding of the assessors or treating personnel, or for the use of intention-to-treat analysis. Most studies performed poorly on the randomization process, allocation concealment, reliability of outcomes measurement, and power calculations. Ten of the 23 quasi-experimental studies scored 5 and above, out of a total possible 9 points.[33,35,37,41,44–46,53,56,57] The scores ranged from 2/9 to 6/9 with a median of 4/9. The lack of reliability in the outcome measurements was a common problem. Studies also performed poorly on the following criteria: ensuring similar other exposure/treatment, having a control group, having adequate follow-up, and performing power calculations.

Table 1
Summary of Study Characteristics and Results

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Cetin et al 2018 RCT	N = 50; 29 females 21 males Mean age 56.4 (11.3); Unilateral Posterior Canal BPPV	Experimental: Epley Maneuver (25) Control: Brandt-Daroff exercise (25)	1. Recovery rates 2. Recurrence Week 1 after treatment Week 2 Week 3 Average follow-up of 18 mo	For Epley Maneuver group only: Recovery rates: Week 1-19 (76%) Week 2-24 (96%) (cumulative) Week 3-25 (100%) (cumulative) Recurrence: 7/25 (28%)
Chang et al 2008 RCT	N = 26; Mean age 54.1 (10.9); Unilateral Posterior Canal BPPV	Experimental: Canalith Repositioning Maneuver + Vestibular exercises (13) Control: Canalith Repositioning Maneuver (13)	1. Standing on foam 2. Single-leg stance 3. Tandem walk 4. Dynamic Gait Index 5. Visual analog scale (dizziness intensity) Baseline 2 wk 4 wk	In total, 12/13 (92.3%) in the Canalith Repositioning Maneuver only group achieved a negative Dix-Hallpike Test. Number of subjects with normal sway velocities at the end of the study: Foam eyes open 12/13 (92%); eyes closed 5/13 (38%) Single-leg standing eyes open 13/13 (100%); eyes closed 1/13 (8%) Tandem walk end-sway 7/13 (54%) Dynamic Gait Index: from 19.8 (2.8) to 22.5 (1.4) ($P < .01$) Visual analog scale (dizziness intensity): from 5.1 (1.6) to 1.0 (1.0) ($P < .01$)
Cohen and Kimball 2005 RCT	N = 124; Mean age 58.3 (12.8); Unilateral Posterior Canal BPPV	Experimental: Canalith Repositioning Procedure (24) Lempert Maneuver (25) Brandt-Daroff Exercise (25) Habituation Exercise (25) Control: Sham Maneuver (25)	1. Visual analog scale (vertigo intensity) 2. Visual analog scale (vertigo frequency) 3. Sensory Organisation Test condition 5 score Baseline 1 wk 3 mo 6 mo	The Canalith Repositioning Procedure, Lempert Maneuver, and Brandt-Daroff groups performed better than the Habituation Exercise and Sham Maneuver groups 1.Vertigo Intensity and frequency: decreased sharply and significantly in the first 60 and 90 d, respectively ($P < .0001$), then plateaued 2. Sensory Organisation Test condition 5 score: 57% of subjects with abnormal baseline scores had sharp improvements in the first 60 d ($P < .0001$) *but* leveled off after that
Gamiz and Lopez-Escamez 2004 QE	N = 32; Mean age (y) 66.8 ⊥ 5.7; Unilateral Posterior Canal BPPV;	Experimental: A single Particle Repositioning Maneuver without mastoid oscillation (32) Control: Nil	1. Dix-Hallpike Test 2. 36-Item Short Form Survey (SF-36) 3. Dizziness Handicap Inventory −short (DHI-S) Baseline 30 d	Dix-Hallpike Test: Negative: 24/29 (83%); Positive: 5/29 (17%) 36-Item Short Form Survey: All domains had significant improvements except Physical Function, Role limitation due to emotional problems, and General Health. Domains that did not normalize: Role limitation due to physical problems and Role limitation due to emotional problems. Dizziness Handicap Inventory−short (out of 40): 17.19 (9.06) → 9.70 (10.13) ($P < .0001$)
Giacomini et al 2002 QE	BPPV group = 20; Mean age (y) 45.0 (3.6); Unilateral Posterior Canalithiasis with resolution of BPPV within 3 d after undergoing Canalith Repositioning Maneuver; Normal controls = 20; Age and gender matched	Experimental: Canalith Repositioning Maneuver (20) Control: Nil	1. Static posturography 1 h after diagnostic maneuver (baseline) 3 d (compared with baseline and 12 wk) 12 wk (compared with 3 d post treatment and normal controls)	Sway velocity (mean): Eyes open: Baseline 8.3 (3.1) (significantly different from control) 3 d 9.4 (2.9) 12 wk 5.4 (2.9) (not significantly different compared with control) Eyes closed: Baseline 11.0 (2.4) (significantly different from control) 3 d 12.3 (4.0) 12 wk 9.6 (3.0) (not significantly different compared with control) Baseline: significant differences in lateral and anterior-posterior planes of body sway between the BPPV and Control group ($P \leq .05$) 3 d: significant within-group changes from baseline ($P < .05$) only seen in frontal (x) plane for the BPPV group. 12 wk: Significant within-group changes from 3 d ($P < .05$) only seen in sagittal (y) plane for the BPPV group. No significant between-group differences found at 12 wk for all parameters.

(*continued on next page*)

Table 1 (*continued*)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Girolamo et al 1998 QE	BPPV group = 32; Idiopathic Posterior Canal BPPV; Mean age (y) Female 51.6 Male 53.0; Normal controls = 32; Age and gender matched	Experimental: Lempert Maneuver (32) Control: Nil	1. Sensory Organisation Test (SOT) Baseline 3 d 1 mo	SOT scores (n = 30 Resolved BPPV): Baseline →1 mo Composite 64.0 (12.7) → 72.0 (7.6) Somatosensory 97.0 (40.0) → 100.0 (10.0) Visual 74.0 (23.0) → 82.0 (18.0) Vestibular 48.0 (24.0) → 67.0 (17.0) Preferential 95.0 (17.0) → 89.0 (9.0) Significant improvements from baseline ($P \leq .05$) but still differs significantly from those of the normal controls ($P < .05$) for conditions 2-6
Hoseinabadi et al 2016 QE	N = 30; Unilateral Posterior Canal BPPV; Group A: With otolith problems = 15; Mean age (y) 44.8 (9.7) Group B: Without otolith problems = 15; Mean age (y) 45.5 (7.4) Vestibular Evoked Myogenic Potential test was used to determine presence of otolith problems	Experimental: Epley Maneuver (30) Control: Nil	1. Dizziness Handicap Inventory -Total -Functional -Emotional -Physical Baseline 1 mo after successful treatment	Dizziness Handicap Inventory (DHI): Total score Baseline: Group A 34.13 (7.65); Group B 25.46 (10.23) ($P = .02$) 1 mo: Group A 9.20 (8.16); Group B 4.13 (5.26) ($P = .05$) 1 mo after successful treatment Group A results: DHI Total, Physical and Functional scores, differed significantly from those of Group B ($P \leq .05$)
Józefowicz-Korczyńska et al 2018 QE	N = 9; Mild traumatic brain injury (MTBI) with BPPV; 8 posterior canal BPPV 1 lateral canal BPPV; Mean age (y) 42.3 (18.7); 4 females 5 males	Experimental: Epley Maneuver (8) Barbeque Roll (1) Control: Nil	1. BPPV occurrence 2. Treatment outcome 3. Recurrence Baseline 2 wk after treatment 4 wk	BPPV occurrence: -Out of 179 cases, 19 complained of positional vertigo. -9 of 19 had BPPV confirmed through positional tests Treatment outcome: 4/9 (44.4%) required a second maneuver 2 wk after initial treatment thereafter tested negative on positional tests Recurrence: 1/9 (12.5%) had a recurrence at 2 y follow-up
Kahraman et al 2016 QE	N = 32; 30 posterior BPPV 2 lateral BPPV Mean age 52.0 (14.2) Normal controls = 32; Age and gender matched; Mean age (y) 52.9 (15.3)	Experimental: Modified Epley or Barbeque Maneuver (as appropriate) (30) Control: Nil	1. Beck Anxiety Inventory 2. Panic Agoraphobia questionnaire 3. Time to end of vertigo and unsteadiness Baseline 7 d 14 d 6 mo	Success rate 1st treatment: 68.8%; 2nd treatment: 90.6% Beck Anxiety Inventory Baseline: 20.91 (12.31) → 14 d: 4.93 (7.00) (both results were significantly worse when compared with controls, $P < .05$) Panic agoraphobia Baseline: 27.84 (17.60) → 14 d: 6.56 (6.33) (both results were significantly worse when compared with controls, $P < .05$) Mean time (d) to: Negative positional tests, 11.16 (8.60) Correction of vertigo, 32.69 (24.68) Correction of unsteadiness, 25.41 (28.60)
Kaur and Shamanna 2017 Randomized trial	N = 90; 43 females 47 males Age range (y) 20 to 60 Epley only group = 30; Age mean (y) 41.3 (11.4) Betahistine only group = 30; Not given Epley + Betahistine group = 30; Age mean (y) 42.1 (13.0) All 3 groups were age- and gender- matched	Unclear which were the experimental or control groups Epley vs Betahistine vs Epley + Betahistine	1. Treatment efficacy 2. Visual analog scale (VAS) vertigo 3. Dizziness Handicap Inventory (DHI) 1 wk after treatment 4 wk	Epley only group: Treatment efficacy: -1 subject did not respond to treatment at all -1 subject (3.3%) had a recurrence at 4 wk VAS (mean) Pretreatment 7.80 (0.94) 1 wk posttreatment 2.40 (1.28) 4 wk posttreatment 2.17 (1.28) (significant changes with $P = .001$) DHI Significant improvement (−40 points) from pretreatment ($P < .001$)

Khatri et al 2005 QE	N = 62; Posterior canal BPPV; Subject gender ratio and age were not provided.	Experimental: Canalith Repositioning Maneuver: -with mastoid oscillation (28) -without mastoid oscillation (34) Control: Nil	1. Subjective: Visual analog scale: Grade I (complete): no vertigo on provocative head/body positioning during the entire follow-up; Grade II (partial response): >50% reduction on provocative positioning or ill-defined imbalance only Grade III (no response): no definition provided 2. Objective: Dix-Hallpike test: Type I: no positional nystagmus after 1 mo Type II: minimal nystagmus Type III: continued to have positional nystagmus 3. Recurrence After treatment 7-10 d 15-20 d >1 mo 6 mo	Combining both groups (N = 62): Subjective: 7-10 d after treatment Grade I, 32 (51.6%); Grade II, 26 (41.9%); Grade III, 4 (6.5%) 15-20 d Grade I, 50 (80.6%); Grade II, 10 (16.1%); Grade III, 2 (3.2%) >1 mo Grade I, 53 (85.5%); Grade II, 7 (11.3%); Grade III, 2 (3.2%) Objective: 7-10 d after treatment No positional nystagmus (I): 38 (61.3%); Minimal nystagmus (II): 20 (32.3%); Positional nystagmus (III): 4 (6.5%) 15-20 d I, 50 (80.6); II, 10 (16.1%); III, 2 (3.2%) >1 mo I, 54 (87.1%); II, 6 (9.7%); III, 2 (3.2%) Recurrence (n = 38) at 6 mo: 7 (18.4%)
Kim et al 2005 QE	N = 30; Anterior canal BPPV; Mean age (y) 55.5 (9.1) 18 of 30 subjects also had concurrent posterior canal BPPV	Experimental: Canalith Repositioning Procedures (30) Control: Nil	1. Treatment efficacy rated by: -Grade I: All vertigo and nystagmus resolved -Grade II: BPPV resolved, other vertigo remains 2. Recurrence Assessment done 2 wk after final CRP	Treatment efficacy: -Grade I, n = 29 -Grade II, n = 1 Recurrence (n = 4): -13% for anterior BPPV -10% for posterior or lateral BPPV
Kim et al 2015 QE	N = 102; First attack of idiopathic unilateral BPPV -47 posterior canal -51 lateral canal -4 mixed; Mean age (y) 62.8 (13.1); Healthy controls = 50; Mean age (y) 60.1 (range 43-76)	Experimental: Repositioning maneuvers (did not specify the exact ones used) (102) Control: Nil	1. Vestibular evoked myogenic potential (cervical) 2. Vestibular evoked myogenic potential (ocular) Before treatment 2 mo after successful resolution of nystagmus and vertigo	Baseline: Proportion of abnormal vestibular evoked myogenic potential is significantly higher in the BPPV group compared with healthy controls ($P < .01$) Two months after successful treatment: -59 of 102 (57.8%) successfully treated -No significant changes from the initial values for both affected ($P = .32$) and nonaffected ears ($P = .65$)

(continued on next page)

Table 1 (*continued*)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Kollen et al 2006 QE	N = 17; Posterior canal BPPV; Mean age (y) 52 (range 31-66)	Experimental: Semont (17) Brandt-Daroff exercises if Dix-Hallpike test still positive after 2 Semont treatment (8) Control: Nil	1. Dix-Hallpike Test 2. Static Balance: -Sharpened Romberg -Standing on 1 leg 3. Dynamic Balance: -Walking 10 m -Walking 10 m with horizontal head turns -Walking with vertical head turns 4. Visual analog scale: unsteadiness and vertigo 5. Questions on general health and changed activities Baseline 1 mo 6 mo 12 mo	Negative Dix-Hallpike Test: -1 mo: 11/17 (65%); 6 and 12 mo: 14/17 (82%) Static Balance (standing on 1 leg and Sharpened Romberg, eyes open/closed): no significant changes throughout ($P > .05$) Dynamic Balance: Walking speed (m/s) (all changes were significant, $P \leq .05$) Normal 1.10 (0.20) → 1.25 (0.21) Walking with horizontal head turns (speed, m/s) 1.0 (0.24) → 1.2 (0.23) Walking with vertical head movements (speed, m/s) 1.0 (0.20) → 1.2 (0.19) Step length (mean, m): Walk with horizontal head turns Baseline, 0.61; 6 and 12 mo, 0.66 Walk with vertical head movements Baseline, 0.58; 6 and 12 mo, 0.70 Visual analog scale for unsteadiness and vertigo: -Dizziness decreased significantly over 12 mo but for those with resolved BPPV, values did not reach 0. -Unsteadiness (standing and walking) decreased significantly in the first mo ($P < .01$) but remained the same after 12 mo. Nine of 17 subjects still complained of unsteadiness at end of study.
Lopez-Escamez et al 2003 QE	N = 40; Posterior canal BPPV; Mean age (y) 50.1 (13.5) Gender ratio not reported	Experimental: Single Particle Repositioning Maneuver (40) Control: Nil	1. Dix-Hallpike test (at 30 d) 2. 36-Item Short Form Survey 3. Dizziness Handicap Inventory short (DHI-S) Baseline 7 d 30 d	Dix-Hallpike Test (at 30 d): Negative 28/37 (76%); Positive 9/37 (24%) 36-Item Short Form Survey: -30 d: All domains improved except General Health and Role limitation due to emotional/personal problems (no change) Dizziness Handicap Inventory short: Baseline 18.0 (9.91); 30 d 9.54 (9.94) ($P < .001$)
Lopez-Escamez et al 2005 QE	N = 50; Unilateral posterior canal BPPV; -35 females -15 males Mean age (y) 55.1 (15.3)	Experimental: Single Particle Repositioning Maneuver without mastoid oscillation (50) Control: Nil	1. 36-Item Short Form Survey 2. Dizziness Handicap Inventory short Baseline 30 d 60 d 180 d 360 d	Dix-Hallpike Test: 30 d: Negative 40/50 (80%); Positive 10/50 (20%) 180 d: Positive 7/50 (14%) 360 d: Positive 5/50 (10%) Persistent BPPV: 2/50 (4%) Recurrence: 3/50 (7.5%) 36-Item Short Form Survey: -Improvements in Physical functioning, Role limitation due to physical functioning, Social function, Vitality and Mental health ($P > .05$) but only Vitality score reached normative value; -No change: General health, Bodily pain and Role limitation due to emotional/personal problems -No difference in scores between subjects with negative and positive Dix-Hallpike tests after treatment Dizziness Handicap Inventory Short total score [mean, SD not provided]: Baseline, 18.19 → at 360 d, 7.78 ($P < .001$)

Maslovara et al 2012 RCT	N = 96 BPPVs; Dizziness Handicap Inventory total score ≥40 Betahistine group = 48; 31 females 15 males Mean age (y) 52.6 (19-84); Epley group; 30 females 15 males Mean age (y) 53.5 (19–76); Healthy controls = 40; 16 females 24 males Mean age (y) 34.8 (23–56)	Experimental: Betahistine (48) Epley Maneuver (48) Control: Nil	1. Dix-Hallpike Test 2. Dizziness Handicap Inventory 3. 36-Item Short Form Survey 4. Hospital Anxiety and Depression Scale Baseline (T0) 1 wk (T1) 8 wk (T8)	Epley Group only: Positive Dix-Hallpike test: -1 wk, 6.67%; 8 wk, 4.45% Dizziness Handicap Inventory–total (median): -Baseline (T0): 72 (IQR 60.0-84.0) -1 wk (T1): 18 (IQR 16.0-34.0) -8 wk (T8): 10 (IQR 8.0-22.0) 36-Item Short Form Survey: T0, 33.01; T1, 58.44; T8, 72.96 Hospital Anxiety and Depression Scale: Anxiety (mean) T0, 1.58 (0.30); T1, 0.98 (0.53); T8, 0.94 (0.21) Depression (mean): T0, 1.48 (0.26); T1, 1.34 (0.15); T8, 1.32 (0.12)
Maslovara et al 2017 QE	N = 40; Posterior canal BPPV; -29 females -11 males Mean age (y) 64 (12)	Experimental: Epley Maneuver (40) Control: Nil	1. Recurrence 2. Vitamin D serum level 3. Calcium serum level After diagnosis (before treatment) 6 mo after	Recurrence: -5 of 31 (16%) (did not provide reason for the difference in sample size) -No significant correlation with age, gender, vitamin D, and calcium levels ($P > .05$) Vitamin D serum level: -Inadequate or deficient in 82.5% of the subjects -Low levels more frequent in canalithiasis cases (6/9) compared with cupulolithiasis cases (5/10) (χ^2 test, $P = .036$) -Canalithiasis cases had a significantly lower level (median 18, IQR 15-20) compared with cupulolithiasis cases (median 27, IQR 22-32) ($P = .013$) Calcium serum level: No significant abnormality in levels or differences between canalithiasis and cupulolithiasis types ($P > .05$)
Mendes et al 2017 QE	N = 48; 33 females 15 males Median age (y) 63 (range 53-69)	Experimental: Epley Maneuver (48) Control: Nil	1. Vestibular evoked myogenic potential (VEMP) test: ocular (oVEMP) and cervical (cVEMP) using (i) latency; (ii) peak-to-peak amplitude (PPA); and (iii) amplitude ratio (AR) 2. Recurrence Before Epley After Epley 7 d after Epley 6 mo after successful repositioning	Treatment efficacy: 2 repositioning procedures: 32/48 (66.7%) 4 repositioning procedures: 48/48 (100%) cVEMP: -No significant changes for all parameters (latency, PPA, and AR) across all measurements for both affected and nonaffected ears ($P > .05$) oVEMP: -No significant changes to latencies measured throughout ($P > .05$) -Increase in PPA for both ears up to 6 mo after treatment but not significant ($P > .05$) -Significant improvements were seen in AR comparing (1) baseline and 7 d after Epley ($P = .011$) and (2) repeated measurements at all time points ($P = .039$) Recurrence: -9/48 (18.8%), with significant difference in both oVEMP AR and cVEMP AR between those with and without recurrence ($P < .05$) -oVEMP AR: the only significant predictor of recurrence (77.8% sensitivity, 94.9% specificity, $P = .002$)
Mujeeb and Khan 2000 QE	N = 21; 14 females 7 males Mean age (y) 46.6 (47%: between 40 and 60 y old)	Experimental: Epley Maneuver + mastoid vibration (21) Control: Nil	1. Success of treatment: Grade I: Negative Hallpike test after Epley Grade II: Some vertiginous feeling on Hallpike test, although with considerable subjective improvement. Grade III: No subjective improvement and a positive Hallpike test 2. Recurrence Timelines not stated. Only mentioned "Follow-up ranged from 30 weeks to 112 weeks"	Success of treatment: Initial Grade I – 15 (71.4%); Grade II – 6 (28.6%); Grade III – 0 Final Grade I, 20 (95.2%); Grade II, 1 (4.85%); Grade III, 0 Recurrence: 3/21 (14.2%) within first 3 wk

(continued on next page)

Table 1 (*continued*)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results
Nunez et al 2000 QE	N = 168; After 17 dropped out, 151 remained; 107 females 44 males Mean age (y) 63.0	Experimental: Canalith Repositioning Procedure ± mastoid vibration or manual tapping (151) Control: Nil	1. Treatment success 2. Recurrence Yearly phone calls were made for follow-ups	Treatment success: First treatment 131/151 (86.8%) Second treatment 138/151 (91.3%) Recurrence: 37/138 (26.8%) Mean time to recurrence (mo) 13.6 (9.7)
Ouchterlony et al 2016 QE	3 groups: Group 1 Traumatic brain injury (TBI) + posterior canal BPPV = 21; 6 females 15 males Age (median years, IQR) 32.0 (21.0); 16 mild TBI 5 moderate TBI Group 2 TBI + nonspecific dizziness (NSD) = 23; 11 females 12 males Age (median years, IQR) 36.0 (26.0); All mild TBI Group 3 TBI + no dizziness group = 12; 5 females 7 males Age (median years, IQR) 43.0 (26.3) All mild TBI	Experimental; Canalith Repositioning Procedure (21) for Group 1 only Control: Nil	1. Symptom resolution 2. 36-Item Short Form Survey (Physical and Mental Health components only) 3. Dizziness Handicap Inventory Baseline 1 wk 5 wk 9 wk 12 wk	TBI with BPPV group only (n = 16): Symptom resolution at 12 wk Resolved 12 (75%); Unresolved 4 (25%) 36-Item Short Form Survey: Although there was improvement in the Physical component scores over 12 wk, the changes in the Mental Health component were negligible. Dizziness Handicap Inventory (mean ± SEM): Baseline 42.9 ± 5.7 12 wk 17.8 ± 5.9 ($P \leq .05$)

Pollak et al 2012 QE	N = 37; Idiopathic BPPV; 32 posterior canals 5 horizontal canals; 23 females 14 males Mean age (y) 59.2 (14.5)	Experimental: Particle Repositioning Maneuvers (as appropriate for the problem) (37) Control: Nil	1. Dizziness Handicap Inventory 2. The Illness Perception Questionnaire–Revised 3. The Intolerance of Uncertainty Scale 4. The State-Trait Anxiety Inventory Baseline 2-3 mo later while free of vertigo	Dizziness Handicap Inventory (DHI): Total score (mean) Before treatment, 29.6 (17.1); after treatment, 24.3 (19.7) ($P = .105$) (DHI-f) Functional subscore (mean) Before, 11.2 (7.7); after, 9.4 (8.9) ($P = .151$) (DHI-e) Emotional subscore (mean) Before, 6.5 (6.0); after, 6.2 (6.8) ($P = .752$) (DHI-p) Physical subscore (mean) Before, 11.7 (5.6); after, 8.7 (6.3) ($P = .019$) The Illness Perception Questionnaire–Revised (IPQ-R) (mean): Before, 109.3 (16.7); after, 109.2 (12.1) ($P = .942$) The Intolerance of Uncertainty Scale (IUS) (mean): Before, 73.8 (20.6); after, 70.0 (20.2) ($P = .191$) The State-Trait Anxiety Inventory (STAI): State anxiety (STAI-S) (mean) Before, 39.4 (14.2); after, 38.0 (13.4) ($P = .524$) Trait anxiety (STAI-T) (mean) Before, 39.7 (11.1); after, 38.5 (10.5) ($P = .347$) Correlations: -Belief in consequences (IPQ-R-3) of the disease with DHI (functional and emotional) ($r = 0.3$), and trait anxiety levels of the patients (STAI-T) ($r = 0.3$) ($P < .05$) -Belief in personal control of the condition (IPQ-R-4) with the belief in treatment control (IPQ-R-5) ($r = 0.4$) and the understanding of the disease (IPQ-R-6) ($r = 0.3$) ($P < .05$) -Belief in treatment control (IPQ-R-5) and the understanding of the disease (IPQ-R-6) ($r = 0.6$) ($P < .001$) -Intolerance of Uncertainty Scale with DHI-emotional subscore ($r = 0.3$), the State and Trait Anxiety Inventory ($r = 0.4$) and belief in consequences of the disease (IPQ-R-3) ($r = 0.3$) ($P < .05$)
Propakis et al 2005 QE	N = 592; 302 females 290 males Mean age (y) 59 (range 18-84) Posterior canal: 521 (88%) Horizontal canal: 59 (10%) Anterior canal: 12 (2%)	Experimental: Epley's variant for posterior and anterior canal BPPV (533) Barbeque roll for horizontal canal BPPV (59) Control: Nil	1. Treatment success 2. Recurrence Baseline 48 h after treatment 7 d Phone contact every 6 mo	Treatment success: Initial Canalith Repositioning Procedure (CRP), 497/592 (84%) 2 CRP, 60 (10%) 3 CRP, 19 (3.1%) >3 CRP, 16 (2.7%) Long term, 516/592 (87%) 74% complained of instability or light-headedness for first 48-72 h after CRP Recurrence: 72/592 (12%) in a mean follow-up period of 46 mo 23/72 were >70 y old
Prokopakis et al 2013 QE	N = 965; 484 females 481 males Age range 18-87 y old Posterior canal: 849 (88%) Horizontal canal: 96 (10%) Anterior canal: 20 (2%)	Experimental: Epley's variant for posterior and anterior canal BPPV (869) Barbeque roll for horizontal canal BPPV (96) Control: Nil	1. Treatment success 2. Recurrence Baseline 48 h after 7 d Phone contact every 6 mo	Treatment success: Initial Canalith Repositioning Procedure (CRP), 819/965 (85%) 2 CRP, 88 (9%) 3 CRP, 39 (4%) >3 CRP, 19 (2%) 83% complained of instability or light-headedness for first 48 h after CRP Recurrence: 139/965 (15.5%) in a mean follow-up of 74 mo. -more in those with older age and history of head trauma or vestibular neuropathy ($P < .001$)

(continued on next page)

Table 1 (*continued*)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results	
Rashad 2009 QE	N = 269; Posterior canal BPPV; Completed study (n) = 103; 58 females 45 males Mean age (y) 48.2 (11.1)	Experimental: Epley Maneuver Control: Nil	1. Subjective health (overall): -Complete cure ->50% improvement -<50% improvement -No improvement -Worse 2. Recurrence (over 5 y) Baseline 2 wk after treatment 1 mo 3 mo 6 mo 12 mo 5 y	1-y follow-up (n = 196) and 5-y follow-up (n = 103): Subjective Health: At 1 y -Complete cure, 95 (92%) ->50% improvement, 7 (7%) -<50% improvement, 1 (1%) -No improvement, 0 -Worse, 0 At 5 y -Complete cure, 67 (65%) ->50% improvement, 22 (21%) -<50% improvement, 11 (11%) -No improvement, 3 (3%) -Worse, 0	Recurrence: 1 y Rate, 26/103 (25%) Time to recurrence (mean), 3.5 (1.0) wk 5 y Rate, 37/103 (35%) Time to recurrence (mean), 46.3 mo Independent predictor: BPPV duration ≥3 y or more (OR 162.5, 30.97-852.7, $P < .001$)
Ribeiro et al 2016 RCT	N = 16; Chronic BPPV (min duration 6 mo without treatment) and ≥65 y old Canalith Repositioning Maneuver (CRM) + Vestibular Rehab = 7; 6 females 1 male Median age (y) 69 (65-78); CRM only = 7; 5 females 2 males Median age (y) 73 (65-76)	Experimental: CRM + Vestibular Rehab (7) Vestibular Rehab started 1 wk (T1) after treatment Control: CRM (7)	1. Dix-Hallpike Test 2. Recurrence Baseline (T0) 1 wk (T1) 5 wk (T5) 9 wk (T9) 13 wk (T13)	Initial CRM efficacy for all BPPV cases based on Dix-Hallpike Test at T1: Positive: 11/14 (78.6%) Negative: 3/14 (21.4%) Recurrences (all BPPV cases) at 13 wk: 3/14 (21.4%)	
Ribeiro et al 2017 RCT	N = 16; Chronic BPPV (min duration 6 mo without treatment) and ≥65 y old Canalith Repositioning Maneuver (CRM) + Vestibular Rehab = 7; 6 females 1 male Median age (y) 69 (65-78); CRM only = 7; 5 females 2 males Median age (y) 73 (65-76)	Experimental: CRM + Vestibular Rehab (7) Control: CRM (7)	1. Modified Clinical Test of Sensory Integration on Balance (mCTSIB) 2. Unipedal stance 3. Limits of Stability 4. Walking across speed 5. Tandem walk 6. Dynamic Gait Index (DGI) 7. Visual analog scale (dizziness intensity) 8. Dizziness Handicap Inventory Baseline (T0) 1 wk (T1) 5 wk (T5) 9 wk (T9) 13 wk (T13)	For CRM-only group: mCTSIB: significant improvement ($P < .05$) seen only in the Foam eyes closed and composite scores. No significant improvement in Unipedal stance sway velocity (eyes open/closed), Limits of Stability, Walking across speed, Tandem walk end sway, and DGI ($P > .05$) Visual Analogue Scale (dizziness intensity): T0, 8 (5-10); T13, 1 (0–4) ($P < .05$) Dizziness Handicap Inventory (DHI): (all changes $P < .05$) DHI Total T0, 40 (22-70); T13, 10 (4-24) DHI Physical T0, 16 (12-24); T13, 2 (0-10) DHI Functional T0, 18 (4-30); T13, 4 (2-14) DHI Emotional T0, 10 (2-16); T13, 2 (0-4) For the experimental group, significant improvements ($P < .05$) in static balance but no significant difference ($P > .05$) when compared with CRM-only group. There were significant improvements in dynamic balance ($P < .05$) within group. Significant between-group differences were seen for DGI, Tandem walk and Limits of Stability max. excursion ($P < .05$)	

Salvinelli et al 2004 RCT	N = 156; Mean age 74 (70-80); Posterior canal BPPV Lempert Maneuver = 52; 39 females 13 males Mean age (y) 73 (70–78) Flunarizine = 52; 32 females 20 males Mean age (y) 74.5 (71-80) Control = 52; 34 females 18 males Mean age (y) 75 (72–79)	Experimental: Lempert Maneuver (52) Medication—flunarizine (52) Control: No treatment (52)	1. Treatment success 2. Relapse of BPPV 3. Vestibular Disorders Activities of Daily Living – activities of living and quality of life (only in those with symptom resolution): i.Standing from sitting on the bed or chair ii.Walking in open spaces iii.Light household chores iv.Traveling around the community Baseline 6 mo	Repositioning maneuver group only (n = 52): Treatment success: First session 44 (85%) Second session 46 (88% Third session 49 (94%) Relapse: 2/52 (3.8%) Vestibular Disorders Activities of Daily Living: No results reported. Only the following statement under "Results" section—"A statistically significant post-treatment improvement in activities of daily living and in quality of life was noticed ($P < .001$)."
Sato et al 2013 QE	N = 197; Posterior canal BPPV 140 females 57 males Mean age (y) 61.5 (15.6) Etiology: Idiopathic = 152 Secondary = 40 (head trauma = 8 prolonged bedrest = 14 inner ear disease = 18)	Experimental: Single Epley Maneuver without mastoid oscillation (197) Control: Nil	1. Dix-Hallpike Test 2. Time course to remission of residual positional vertigo Baseline 7 d after Epley 1 mo 3 mo	Negative Dix-Hallpike Test at 7 d: Idiopathic, 115 (73%) Head trauma, 2 (25%) Prolonged bedrest, 3 (36%) Inner ear disease, 10 (56%) Residual positional vertigo: 1 mo → 3 mo Idiopathic, 6.7% → 2.3% Head trauma, 50% → 25% Prolonged bedrest, 41.7% → 8.3% Inner ear disease, 6.1% → 2.3%
Sekine et al 2006 RCT	N = 190; Mean age (y) 58.9 (15.4); Posterior canal BPPV (P-BPPV) 127 Horizontal canal BPPV (H-BPPV) 63 Modified Epley/Lempert Maneuver = 96 57 females 39 males (67 P-BPPV and 29 H-BPPV) Mean age (y) 58.7 (15.5) Controls = 94; 55 females 39 males (60 P-BPPV and 34 H-BPPV); Mean age (y) 59.1 (15.3)	Experimental: P-BPPV: Modified Epley (67) H-BPPV: Lempert Maneuver (29) Control: No treatment (94)	1. Time course in remission of positional vertigo 2. Residual rate of positional vertigo 1 wk 1 mo	Residual rate of positional vertigo in successfully treated subjects: Posterior canal BPPV 1 wk: Modified Epley, 22.7% No treatment (Control), 51.7% 1 mo: Modified Epley, 9.7% Control, 20.0% Horizontal canal BPPV 1 wk: Lempert, 21.4% Control, 30.9% 1 mo: Lempert, 5.4% Control, 7.1% ($P = .375$)

(continued on next page)

Table 1 (*continued*)

Study/Design	Subjects	Experimental/Control Interventions (n)	Outcomes/Timelines	Results	
Sridhar et al 2003 RCT	N = 40; Age range (y) 18 to 72 Ratio of females/males: 1:1 Particle Repositioning Maneuver (PRM) = 20; Median age (y) 38.5 Placebo = 20; Median age (y) 45	Experimental: PRM (20) Control: Placebo (20)	1. Symptom resolution: Grade I: complete resolution of symptoms; Grade II: partial resolution of symptoms; Grade III: no resolution or worsening of symptoms 2. Recurrence Baseline 1 wk 4 wk 3 mo 6 mo 9 mo 12 mo	For PRM group only: 1 wk: Negative Dix-Hallpike Test, 20 Complete resolution (of symptoms), 19 4 wk: Negative Dix-Hallpike Test, 19 Complete resolution, 19 Recurrence, 1 3 mo: Negative Dix-Hallpike Test 18 Complete resolution, 19 Recurrence, 2	6 mo: Negative Dix-Hallpike Test, 19 Complete resolution, 19 Recurrence, 1 9 mo: Negative Dix-Hallpike, 17 Complete resolution, 17 Recurrence, 3 12 mo: Negative Dix-Hallpike Test, 18 Complete resolution, 18 Recurrence, 2
Tan et al 2017 QE	N = 88; BPPV with hypertension (h-BPPV) group = 41; 27 females 14 males Age mean (y) 53.4 (9.8) Idiopathic BPPV (i-BPPV) = 47; 28 females 19 males Age mean (y) 51.64 (12.21)	Experimental: Canalith Repositioning Procedure or Barbeque Maneuver as appropriate (88) Control: Nil	1. Treatment success 2. Recurrence 3. Clinical characteristic differences between the 2 groups Follow-ups after diagnosis: 1 wk 4 wk 3 mo	Treatment success (1 wk, 4 wk and 3 mo): h-BPPV – 31 (75.6%), 39 (95.1%), 40 (97.6%) i-BPPV – 38 (80.9%), 46 (97.9%), 47 (100%) Recurrence: h-BPPV—13 (31.7%); 6 single + 7 multiple recurrences i-BPPV—6 (12.8%); 2 single + 4 multiple recurrences Clinical characteristic differences between the 2 groups: h-BPPV group had significantly fewer initial BPPV episodes than i-BPPV (51.2% vs 74.5%, $P = .024$) and significantly longer median episode duration compared with the i-BPPV group (60 d vs 15 d, $P = .017$). No significant differences in age, gender, and side of lesion ($P > .05$)	
Wang et al 2018 Cohort Study	N = 74; Primary BPPV (Posterior Canal/Horizontal Canal/Mixed) Recurrent group = 25; 17 females 8 males Age mean (y) 63.5 (12.3) Nonrecurrent group = 42; 22 females 20 males Age mean (y) 64.26 (12.21) Dropout: 7	Repositioning maneuvers as appropriate for posterior canal and horizontal canal-BPPVs	1. Recurrence 2. Pittsburgh Sleep Quality Index (PSQI) 3. Predictors of recurrence 2 y after successful repositioning treatment	Recurrence: 25/67 (31.3%) PSQI (median, IQR): Recurrent group, 10 (4–13) Nonrecurrent group, 3 (1-7.75) No significant differences were found in PSQI when grouped by age, gender, and BPPV types ($P > .05$) Predictors of recurrence: PSQI—the only independent predictor after adjusting for age, gender, BPPV types, and diabetes (OR 1.17, 95% CI 1.04-1.32, $P = .0082$)	
Yimtae et al 2003 RCT	N = 58; Posterior Canal BPPV Modified Canalith Repositioning Maneuver = 29; 25 females 4 males Age mean (y) 44.0; Unilateral, 27 Bilateral, 2 Medication = 29; 18 females 11 males Mean age (y) 48.0 Unilateral, 28 Bilateral, 1	Experimental: Modified Canalith Repositioning Procedure + Cinnarizine and instructions to take for vertigo (29) Control: Cinnarizine and instructions(29)	1. Rate of effectiveness of treatment 2. Symptom scoring -Stable/worse -Improving -No symptom 3. Time course of recovery 4. Total number of times of taking medications Baseline 1 wk 4 wk	Modified Canalith Repositioning Procedure group (n = 29): Rate of effectiveness of treatment: 75% Symptom grading at 4 wk (post BPPV resolution) (n = 25): -Stable/worse, 1/25 (4%) -Improvement, 8/25 (32%) -No symptoms, 16/25 (64%) Time course of recovery (negative Dix-Hallpike Test): Faster with Canalith Repositioning; median difference = 3 wk; 95% (CI 2.55%-3.45%) ($P = .02$) Total no. of times of taking medications: Canalith Repositioning Maneuver group, 5.8 (2.0), vs Medication group, 23.0 (4.4)	

Table 2
Quality Appraisal of Randomized Controlled Trials Using JBI Critical Appraisal Tools

	Cetin et al 2018	Chang et al 2008	Cohen and Kimball 2005	Kaur and Shamanna 2017	Maslovara et al 2012	Ribeiro et al 2016	Ribeiro et al 2017	Salvinelli et al 2004	Sekine et al 2006	Sridhar et al 2003	Yimtae et al 2003
True randomization	X	Unclear	Unclear	Unclear	Unclear	√	√	X	X	√	Unclear
Allocation concealment	Unclear	√	Unclear	Unclear	Unclear	√	√	Unclear	X	Unclear	Unclear
Similar baseline characteristics	√	√	Unclear	√	√	√	√	Unclear	√	X	√
Blinding—participants	√	X	X	√	X	X	X	X	X	√	Unclear
Blinding—treating staff	Unclear	X	X	Unclear	Unclear	X	X	Unclear	X	Unclear	Unclear
Blinding—assessors	Unclear	√	√	Unclear	Unclear	√	√	Unclear	X	Unclear	√
Similar other treatment*	√	Unclear	√	X	√	√	√	√	Unclear	Unclear	√
Adequate follow-up	√	√	√	Unclear	Unclear	√	√	√	Unclear	√	X
Participant analyzed in assigned group†	Unclear	Unclear	No	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Outcomes measured similarly throughout	√	√	√	√	√	√	√	√	√	√	√
Outcomes measured reliably	Unclear	√	Unclear	Unclear	X	Unclear	Unclear	X	X	X	X
Appropriate statistics analysis	√	X	√	X	X	X	X	√	X	√	√
Design appropriate/deviation	√	√	X	√	√	√	√	√	√	√	√
Total score	7/13	7/13	5/13	4/13	4/13	8/13	8/13	5/13	3/13	6/13	6/13

NA, not applicable; √, yes; X, no.
*Use or control of use of vestibular suppressants rated as "Unclear" if not clearly stated (excluding studies on medications) unless other factors assumed greater significance.
†Intention-to-treat (ITT): considered present when clearly stated.

Table 3
Quality Appraisal of Quasi-experimental Studies Using JBI Critical Appraisal Tools

	Gamiz and Lopez-Escamez 2004	Giacomini et al 2002	Girolamo et al 1998	Hoseinabadi et al 2016	Jozefowicz-Korczynska et al 2018	Kahraman et al 2017	Khatri et al 2005	Kim et al 2005	Kim et al 2015	Kollen et al 2006	Lopez-Escamez et al 2003
Clear cause and effect	√	√	√	√	√	√	√	√	√	√	√
Similar participant characteristics in comparison groups	√	Unclear	Unclear	Unclear	√	√	Unclear	√	√	√	√
Similar other treatment/ exposure*	Unclear	Unclear	Unclear	Unclear	Unclear	√	X	Unclear	Unclear	Unclear	Unclear
Control group	X	√	√	X	X	√	X	X	√	X	X
Multiple measurements pre- and post- treatment/ exposure	√	√	√	√	√	√	√	√	√	√	√
Adequate follow-up	X	Unclear	Unclear	Unclear	√	Unclear	Unclear	Unclear	X	√	X
Outcomes measured similarly throughout	√	√	√	√	√	√	√	√	√	√	√
Outcomes measured reliably	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Appropriate statistical analysis	X	X	X	Unclear	X	X	X	X	X	X	X
Total score	4/9	4/9	4/9	3/9	5/9	6/9	3/9	4/9	5/9	5/9	4/9

	Lopez-Escamez et al 2005	Maslovara et al 2017	Mendes et al 2017	Mujeeb and Khan 2000	Nunez et al 2000	Ouchterlony et al 2016	Pollak et al 2012	Prokopakis et al 2005	Prokopakis et al 2013	Rashad et al 2009	Sato et al 2013	Tan et al 2017
Clear cause and effect	√	√	√	√	√	√	√	√	√	√	√	√
Similar participant characteristics in comparison groups	√	√	√	√	√	X	√	√	√	√	X	X
Similar other treatment/ exposure*	Unclear	Unclear	Unclear	√	X	Unclear	Unclear	X	X	Unclear	Unclear	Unclear
Control group	X	X	X	X	X	√	X	X	X	X	X	√
Multiple measurements pre- and post- treatment/ exposure	√	√	√	√	X	√	√	√	√	√	√	√
Adequate follow-up	X	Unclear	√	√	X	X	Unclear	√	X	X	Unclear	√
Outcomes measured similarly throughout	√	√	√	√	X	√	√	√	√	√	√	√
Outcomes measured reliably	X	Unclear	Unclear	X	X	X	X	X	X	X	Unclear	Unclear
Appropriate statistical analysis	X	X	X	X	X	X	X	√	√	√	√	X
Total score	4/9	4/9	5/9	6/9	2/9	4/9	4/9	6/9	5/9	5/9	4/9	5/9

NA, not applicable; √, yes; X, no.
*Use or control of use of vestibular suppressants rated as "Unclear" if not clearly stated (excluding studies on medications) unless other factors assumed greater significance.

The only cohort study[58] scored 5/11 and lacked clarity in the criteria: reliability/validity of exposure and outcome measurements, adequate follow-up, and appropriate statistical analysis (Tables 2–4).

Results of Individual Studies

The overall efficacy of repositioning maneuvers ranged from 70% to 100% as assessed by the positional tests. Initial treatment efficacy ranged from 61% to 87%.[30,32,34,38,39,41,42,44,45] However, it was reported to be lower (21%-47%) in some studies.[26,36,37] One study reported 73% efficacy rate for BPPV with idiopathic etiology but 25%-56% for BPPV secondary to head trauma, prolonged bedrest, and inner ear disease.[48]

At 1 month, significant improvement in vertigo/dizziness was reported.[27–29,34,37,43,46,50,51] Nevertheless, some reported incomplete resolution of symptoms despite negative positional tests.[34,51] Sekine et al[49] and Sato et al[48] reported residual vertigo in 5% to 10% and 6% to 50% of participants with BPPV, respectively. Another study[33] found the mean time to correction of vertigo and imbalance were 33 and 25 days, respectively, whereas the mean time to BPPV resolution was 11 days. Improvements in static balance, Sensory Organisation Test, and Dynamic Gait Index were reported.[9,27,28] Less favorable results were reported for dynamic balance and balance with eyes closed.[27,28,37] Quality of life (SF-36) and the Dizziness Handicap Inventory scores also improved.[30,38,39,43] However, it was found that participants with concomitant otolith dysfunction continued to have significantly higher Dizziness Handicap Inventory scores, compared to those without otolith problems, 1 month after successful treatment.[32]

Beyond 1 month, despite BPPV resolution, residual vertigo/dizziness and feeling of unsteadiness were reported.[37,48] At 3 months, 2.3% to 25.0% of participants with BPPV of various etiologies still complained of residual vertigo/dizziness.[48] Kollen et al[37] reported that 52.9% of participants continued to feel unsteady at 12 months. The Dizziness Handicap Inventory scores improved significantly from baseline in 4[27,32,40,43] of 5 studies. Quality of life (SF-36) scores showed improvements with repositioning maneuvers in most domains except Role Limitation due to emotional problems[38] and the mental health component.[43] Compared with healthy controls, participants with BPPV had significantly higher anxiety levels.[33,40] Negative emotional beliefs, anxiety and perception persisted even after these participants were "cleared" of BPPV for 3 months (ie, resolution of signs and symptoms on positional tests).[10,33,40] Two studies[35,56] from the older adult group investigated otolithic function using the Vestibular Evoked Myogenic Potential (VEMP) test. One study[35] found that participants with BPPV had a higher proportion of abnormal VEMP results, in both affected and nonaffected ears, compared with healthy controls. Two months after successful treatment, there were no significant improvements in the VEMP for both ears. However, Mendes et al[56] found improvements in the Ocular VEMP amplitude and asymmetrical ratio (AR) parameters after treatment, with AR being the only significant predictor of recurrence (77.8% sensitivity, 94.9% specificity, $P = .002$).

Improvements in outcomes were reported across various studies, most of which did not include a comparison control group. In this article, final results were tabulated and compared with age-matched or close to age-matched data[9,30,31,33,35,38–40,43,59–68] (Table 5). Both younger and older adult groups experienced residual dizziness, recurrences, and less than optimal improvements in various outcomes when compared with normative/comparison data. These outcomes included the Dizziness Handicap Inventory, Dynamic Gait Index and other gait measures, the Sensory Organisation Test, dynamic balance measures, mental health (anxiety), and quality of life.

Recurrence rates ranged from 4% to 18% at 6 months.[34,36,47,50] Prokopakis et al[44] reported 15.5% recurrence rate in a mean follow-up period of 74 months. The authors associated the recurrence with older age and history of head trauma or vestibular neuropathy ($P < .001$). Rashad[46] reported a higher recurrence rate of 35% at

Table 4
Quality Appraisal of Cohort Studies Using JBI Critical Appraisal Tools

	Groups Similar and From Same Population	Similar Measurement for Exposures for Group Allocation	Measurement of Exposure Valid and Reliable	Confounding Factors Identified	Strategies to Deal With Confounding Factors	Participants Free of Outcome at Start	Outcomes Measurement Reliable and Valid	Follow-up Reported and Sufficient	Follow-up Complete; If Not, Adequate Reason Given	Used Strategies to Address Incomplete Follow-ups	Appropriate Statistical Analysis	Total Score
Wang et al 2018	√	√	Unclear	√	√	X	Unclear	√	X	X	Unclear	5/11

√, yes; X, no.

Table 5
Comparison of Treatment Outcomes for Younger and Older Adult Groups With Normative/Comparison Data

	Results as at Study Completion							Normative/Comparison Data
Residual Symptoms	Younger Adults Unknown age group: At 1 mo, negative Dix-Hallpike test 87.1% Complete resolution of symptoms 85.5% (Khatri et al[34])	Mean time (d) to: -Negative positional tests: 11.16 (8.60) -Correction of vertigo: 32.69 (24.68) - Correction of unsteadiness: 25.41 (28.60) (Kahraman et al[33])	Unsteadiness decreased significantly during the initial few mo after treatment but remained the same after 12 mo; 9/17 subjects still complained of unsteadiness at end of study. (Kollén et al[37])	Residual rate of positional vertigo in successfully treated BPPV cases at 1 mo: Posterior canal BPPV 9.7% Horizontal canal BPPV 5.4% (Sekine et al[47])	74% and 83% complained of instability or light-headedness for first 48-72 h after Canalith Repositioning Procedure (Prokopakis et al[44,45])	Symptom grading (4 wk post BPPV resolution): -Stable/worse, 4% -Improvement, 32% -No symptom, 64% (Yimtae et al[31])	Older Adults Residual positional vertigo (at 1/3 mo): Idiopathic 6. 7%/2.3% Head trauma 50%/25% Prolonged bedrest 41.7%/8.3% Inner ear disease ≈ 6.1%/2.3% (Sato et al[46])	Not applicable
Dizziness Handicap Inventory (Total score 100)	Younger adults With otolith problem 9.20 (8.16) Without otolith problem 4.13 (5.26) (Hoseinabadi et al[32])		Median 10 (8.0-22.0) (Maslovara et al[40])	17.8 (5.9) (Ouchterlony et al[43])	24.3 (19.7) (Pollak et al[35])		Older adults Median 10 (4.0-24.0) (Ribeiro et al[27])	5.6 (11.2) (Davalos-Bichara et al[55]) [Data on healthy older adults, mean age 77.2 (6.1) y]
36-Item Short Form Survey (SF-36)	Improvements and normalization reported in most domains. However, domain Role Emotional (RE) consistently did not improve and normalize in the following 3 studies: -Older adults (Gamiz and Lopez-Escamez[30]) -Younger adults (Lopez-Escamez et al[38,39]) Younger adults Total score: 72.96 (Maslovara et al[40]) Component scores: Physical, 44.5 (1.9); Mental Health ≈39 (Ouchterlony et al[43])							The Spanish Population normative data set as mean of 0, with the data of subjects with BPPV plotted in the same graph for comparison (Gamiz and Lopez-Escamez,[30] Lopez-Escamez et al[38,39]) (Intra-study) Total score: 86.42 (Maslovara et al[40]) (Intra-study normal controls) Component scores: Physical, 43.6 (2.8); Mental Health, 46.7 (4.1) (Ouchterlony et al[42]) (Data on traumatic brain injury with no dizziness group) Physical, 50.8-53.6; Mental Health, 50.9-52.6 (Garratt and Stavem[56]) (Normative data for the Norwegian population aged 20 to ≤50 y)
Mental Health	No data on older adults were available. Younger adults only: The State-Trait Anxiety Inventory State anxiety, 38.0 (13.4); Trait anxiety, 38.5 (10.5) (Pollak et al[35]) Intolerance of Uncertainty Scale 70.0 (20.2) (Pollak et al[35])			Beck Anxiety Inventory, 4.93 (7.00) ($P = .031$) Panic Agoraphobia Scale, 6.56 (6.33) ($P < .001$) (Kahraman et al[33]) The Hospital Anxiety and Depression Scale Anxiety, 0.94 (0.21); Depression, 1.32 (0.12) (Maslovara et al[40])				The State-Trait Anxiety Inventory State anxiety, 32.9 (11.1); Trait anxiety, 35.6 (9.9) (Nyenhuis et al[58]) [Data on healthy adults with mean age 44.0 (18.4)] Intolerance of Uncertainty Scale 18-30 y old, 63.55 (22.06); ≥60 y old, 52.15 (18.87) (Gerolimatos and Edelstein[59]) (Data on young and older adults from community) Beck Anxiety Inventory, 2.25 (1.85) Panic Agoraphobia Scale, 0.25 (1.41) (Kahraman et al[33]) (Intra-study) The Hospital Anxiety and Depression Scale Anxiety, 0.88 (0.09); Depression, 1.31 (0.09)

(continued on next page)

Table 5 (*continued*)

	Results as at Study Completion		Normative/Comparison Data
			(Maslovara et al[40]) (Intra-study)
Modified Clinical Test of Sensory Integration of Balance or parts of it -Sway velocity	Younger adults Firm eyes open, 5.4 (2.9); eyes closed, 9.6 (3.0) ($P > .05$) (Giacomini et al[21])	Older adults Firm eyes open, 0.3 (0.1-0.4) (median, range) Firm eyes closed, 0.3 (0.2-0.4) Foam eyes open, 0.7 (0.3-1.2) Foam eyes closed, 1.0 (0.5-6.0) (Ribeiro et al[27])	Firm eyes open, 4.53 (2.3); eyes closed, 8.5 (1.3) (Giacomini et al[21]) (Intra-study) Firm with eyes open 6th decade: 0.213 (0.24) 7th decade: 0.211 (0.09) Firm with eyes closed 6th decade: 0.270 (0.13) 7th decade: 0.325 (0.17) Foam with eyes open 6th decade: 0.656 (0.26) 7th decade: 0.932 (0.75) Foam with eyes closed 6th decade: 2.76 (1.28) 7th decade: 4.04 (1.63) (Choy et al[28]) (Data on females aged 20-80 y old)
Standing on 1 leg	Younger adults Sway velocities (deg/s) Eyes open, 0.58 (0.16) Eyes closed, 9.43 (3.49) (Chang et al[28]) Older adults Eyes open, 8.5 (1.0-12.0) (median, range) Eyes closed, 12.0 (12.0-12.0) (Ribeiro et al[27])	Time (s) Eyes closed, 11 (10) (Kollén et al[37])	Sway velocities (deg/s) Eyes open (right leg) 4th decade, 0.600 (0.16); 5th decade, 1.130 (1.63); 6th decade, 2.350 (3.25); 7th decade, 5.830 (4.37) Eyes closed (right leg) 4th decade, 6.630 (4.03); 5th decade, 8.760 (3.47); 6th decade, 10.520 (2.61); 7th decade, 11.660 (1.46) (Choy et al[28]) (Data on females aged 20-80 y old) Time (s) with eyes closed 4th decade, 27.48 (6.48); 5th decade, 21.77 (9.09); 6th decade, 19.92 (9.81) (Vereeck et al[29]) (Data on adults aged ≥20 y old)
Sensory Organisation Test (SOT) Younger adults[6]	Composite, 72.0 (7.6) Somatosensory, 100.0 (10.0) Visual, 82.0 (18.0)—significantly different from results of control subjects ($P < .05$) for all scores except for Somatosensory Vestibular, 67.0 (17.0) Preferential, 89.0 (9.0)		Composite, 80.0 (3.5) Somatosensory, 98.0 (1.0) Visual, 89.0 (6.0) Vestibular, 71.0 (7.0) Preferential, 100.0 (4.0) (Intra-study)
Dynamic Gait Index (Total score 24)	Younger adults 22.5 (1.4) (Chang et al[28])	Older adults Median 20 (17–22) (Ribeiro et al[27])	4th decade: 24 (0.2); 5th decade: 23.9 (0.4); 6th decade: 23.9 (0.4); 7th decade: 23.2 (0.9) (Vereeck et al[29]) (Data on adults aged ≥20 y old)
Tandem walk end sway velocity (deg/s)	3.90 (1.39) (Chang et al[28])	Median 5.9 (5.1–6.5) (Ribeiro et al[27])	4.26 (1.34) (Park and Jung[57]) [Data on healthy adults, mean age 52.2 (9.6) y old] 3. 6 (1.2) (Lim and Lee[54]) [Data on healthy females with mean age 64.8 (4.1) y old]
Walking Younger adults (Kollén et al[37])	Speed (m/s) Normal speed walking, 1.25 (0.21) Walking with horizontal head turns, 1.2 (0.2) Walking with vertical head turns, 1.2 (0.19)	Step length (m) Walk with horizontal head turns, 0.66 Walk with vertical head turns, 0.70 (Kollén et al[37])	Normal walking speed (m/s), 1.4 (Bohannon,[58] Schmidheiny et al[55]) Walking with horizontal head turns:

Speed (m/s) 1.3 (0.2); step length (m) 0.71	
Walking with vertical head turns:	
Speed (m/s) 1.3 (0.2); step length (m) 0.72	
(Schmidheiny et al[65]) [Data on healthy adults with mean age 44.0 (13.0) y, range 25-70]	
Not applicable	
Recurrences	Younger adults
	28% (follow-up of 18 mo)[32]
	12.5% (follow-up of 2 y)[33]
	3. 3% (follow-up of 4 wk)[34]
	13% for anterior BPPV; 10% for posterior/lateral BPPV (mean follow-up 6.8 mo)[35]
	7. 5% (follow-up of 12 mo)[38]
	14.2% within first 3 wk[41]
	12% (mean follow-up of 46 mo)[45]
	15.5% (mean follow-up of 74 mo)[44]
	25% at 1 y; 35% at 5 y[46]
	21.6% (follow-up of 3 mo)[57]
	Older adults
	16% (follow-up of 6 mo)[55]
	18.8% (follow-up of 6 mo)[46]
	26.8% (mean follow-up 26 mo)[42]
	21.4% (follow-up of 13 wk)[27]
	3.8% (follow-up of 6 mo)[47]
	31.3% (follow-up of 2 y)[58]
	Unknown age group
	18.4% at 6 mo[34]

IQR, interquartile range

5 years, with a similar association with increasing age (≥40 years), but the independent predictor of recurrence was disease duration of 3 years or more at the time of initial treatment.

Comparison of outcomes between older and younger adult groups: meta-analysis

From the numerous outcomes discussed, we managed to pool data to perform meta-analysis for the following: The Dizziness Handicap Inventory (DHI), static and dynamic balance, and recurrence. As the focus was mainly on groups treated only with repositioning maneuvers and different scales were often used for a single outcome, the standardized mean differences for DHI and static and dynamic balance were calculated and pooled using the Generic Inverse Variance method available in the Review Manager software (Version 5.3).[69] Median values were converted to mean (standard deviation) using the median value, minimum and maximum range, and the sample size (n).[70,71]

For DHI, results were pooled from 4 studies[10,32,39,40] for the younger adult group and from 2 studies for the older adult group[27,30] (Figure 2A). The results showed that the younger adult group had more improvement in the DHI scores [−1.84, 95% confidence interval −3.75 to 0.07] compared with the older adult group (−1.00, −4.12 to 2.12). Compared with the younger group, older adults perceived less change in their dizziness-related handicap despite improvement in the BPPV status.

Static balance was pooled from the sway velocity results of standing on firm surface and foam, and standing on 1 leg, with eyes open and closed for each condition. For the younger adult group, there were only 2 relevant studies.[28,31] However, for the older adult group, the results for the various test conditions were pooled from 1 single study[27] as no other studies in the older adult group had the relevant data. A decrease in the sway velocity (negative change) indicated improvement in balance. Both groups appeared to have comparable improvements in static standing balance [older adult group: −0.70 (−1.25 to −0.14) and younger adult group: −0.53 (−0.62 to −0.43) (Figure 2B)]. The heterogeneity (I^2 = 98%, P < .001) in the older adult group results was possibly due to (1) no change at all in single-leg standing with eyes closed from baseline and (2) wide confidential intervals that crossed the line of null effect for standing on foam with eyes closed and single-leg standing with eyes open. Dynamic standing balance was pooled from results of the Dynamic Gait Index (DGI) and the tandem gait end sway velocity. Only results of 1 study from each age group[27,28] were pooled as no other studies were relevant. The timeline for the younger adult group was at 4 weeks as there was no follow-up beyond that. The older adult group results were pooled at 5 weeks (to be comparable with that of the younger group) and at 13 weeks. The change in DGI scores was reversed in direction to align with the directional changes of the tandem gait end sway velocity. From the results, the younger adults group experienced larger improvement (−0.91, −1.60 to −0.23) at short term when compared with the older group (−0.18, −1.54 to 1.17) (Figure 2B). However, the older adult group seemed to continue to experience improvement (effect estimate improved to 1.11) at 13 weeks, although this improvement did not reach statistical significance.

The proportions for recurrence for studies with 6 to 24 months' follow-up time were pooled using the meta-analysis of proportions function available in the MedCalc software (version 18.10.2).[72,73] This timeline was chosen to optimize the number of studies pooled as the follow-up time varied widely across the studies. The pooled recurrence proportion for older adults was 20.5% (I^2 = 80.7%, random effect, 95% confidence interval 11.3-31.7), similar to that of the younger adult group at 18.8% (I^2 = 66.2%, random effect, 95% confidence interval 11.5-27.4).

Discussion

The efficacy of repositioning maneuvers is well established in the literature, and this review revealed similar findings. However, it is

important to note that efficacy has most commonly been measured using positional tests and subjective dizziness/vertigo reports. In addition to these important outcomes, this review also identified physical, functional, and psychoemotional impairments that persisted 1 month or more after the initial repositioning treatment.

Residual dizziness and unsteadiness were reported by several studies in this review. However, these studies did not further establish associative factors to the problem. A recent review on residual dizziness/unsteadiness after physical treatment for BPPV discussed the possible causes as persistent debris in the canal, delayed vestibular adaptation after treatment, other vestibular dysfunctions, duration of vertigo, anxiety, and utricular/otolithic dysfunction.[74] It also reported a prevalence of 31% to 61%, with older adults commonly affected. This contrasted with the prevalence range (2%-52%) and the lack of evidence of residual dizziness in older adults reported in this systematic review. This may be explained by the dearth of relevant studies in the older adult group, hence rendering the findings on residual dizziness in this systematic review inconclusive.

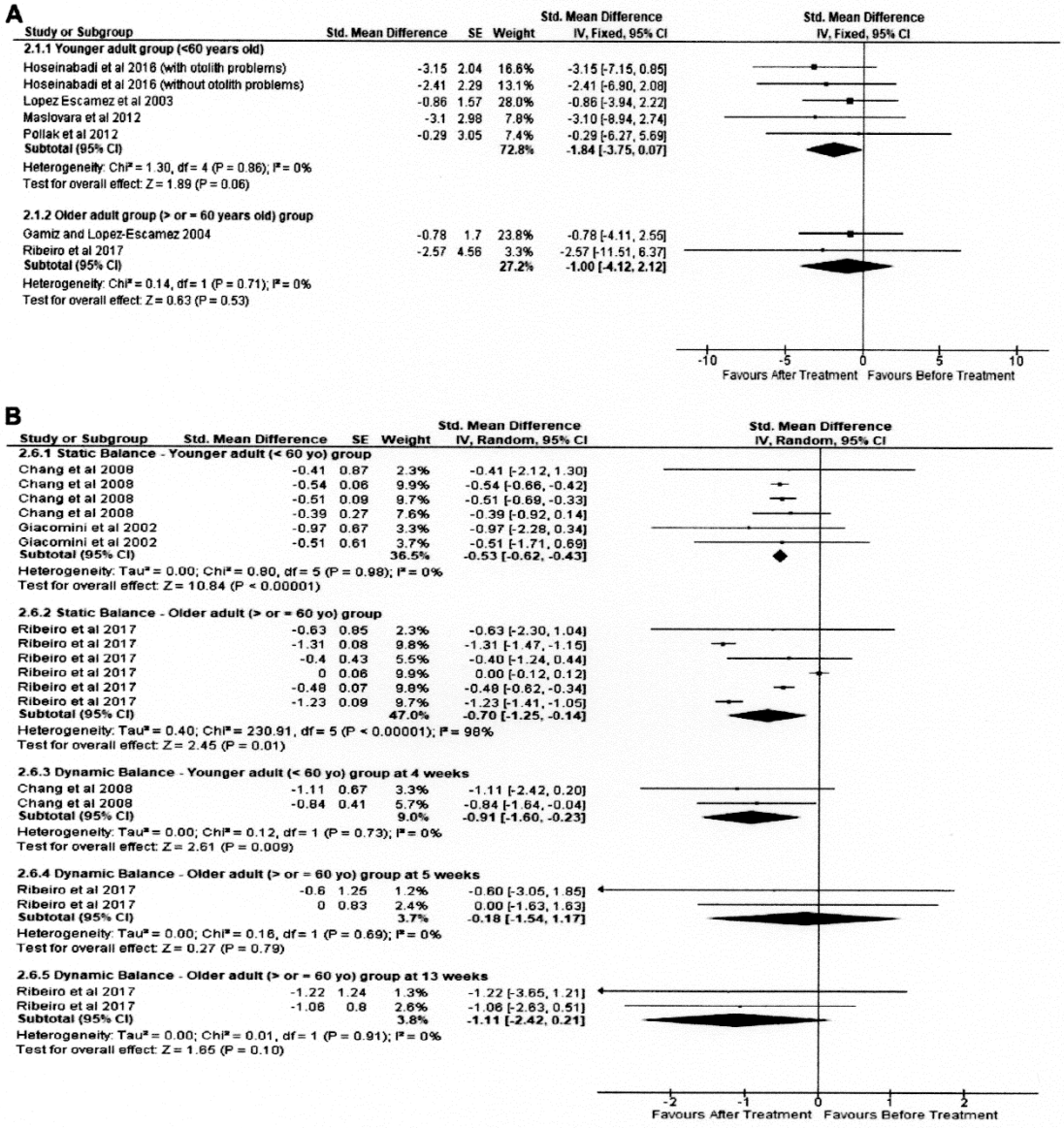


Fig. 2. (A) Forest plot showing results of studies in the younger (<60 years old) and older (≥60 years old) groups for the change in Dizziness Handicap Inventory scores between baseline and final assessments post repositioning maneuvers. (B) Forest plot showing results of studies in the younger and older adult groups for changes in static and dynamic balance after repositioning maneuvers.

Contrary to some reports,[44,75] recurrence proportions were found to be similar between the younger and older adult groups in this systematic review. One major factor could be the lack of exclusively younger or older adult group studies in this systematic review resulting in the lack of significant differences in recurrence. The follow-up time also varied widely across the studies. Better-quality studies with clearer age-differentiated groups and homogenous follow-up timelines are required for conclusive results.

The clinical implications of this review's findings are that, apart from positional tests, patients with BPPV should be further assessed for residual symptoms and gait and balance deficits. Treatment should be prescribed for domains where assessment findings remain subnormal post successful repositioning. Few studies had investigated the mental health impact of BPPV, but the results were consistent: anxiety and negative emotions were frequently present and persisted in many people with BPPV. Hence, these patients should also be monitored for anxiety and negative emotions/moods and be offered timely help if necessary.

Older adults had poorer dynamic balance recovery and higher level of perceived handicap, despite repositioning maneuvers. Failure to address these issues might result in further debilitation and undesired consequences such as falls and functional decline. Falls were not investigated in any studies. Older adults with BPPV have increased fall risks due to impaired balance, especially under vision-denied and altered proprioceptive conditions,[76,77] and vertigo.[78] Additionally, some experienced residual balance impairments 3 months after initial treatment.[27] It is crucial that falls measures be incorporated into future research and management for older adults with BPPV.

Limitations

Several studies with potentially relevant outcomes were excluded as they did not fully meet the inclusion criteria. Short-term recovery from BPPV has been widely reported. However, the focus of this review was on findings beyond 1 month and beyond recovery based solely on positional tests. In general, moderate heterogeneity existed across studies in the areas of outcomes used, follow-up timelines, treatment frequency and dosage, and methodological quality. Meta-analysis could only be performed for some outcomes from a limited number of studies. Research methodology in this area was of low to medium quality, thus limiting the strength of conclusions able to be drawn.

Conclusion and Implications

Consistent with current evidence, repositioning maneuvers were effective in BPPV management if the primary outcome was resolution of signs and symptoms on positional tests. Despite successful repositioning maneuvers, some participants experienced poor outcomes, such as residual dizziness and balance impairment, recurrences, and psychoemotional consequences, that in some cases persisted at 12 months. This review highlights the need to include serial assessment of balance and mental health, as well as patient education, falls measures, and specific treatment to target domains identified as outside of normal limits on assessment. Additionally, older adults experienced less improvements, post repositioning maneuvers, in dynamic standing balance and self-perceived level of handicap when compared with younger adults. These findings underscore the need to focus not just on treating BPPV and improving the symptoms but also on improving physical function and addressing the handicap effects caused by BPPV symptoms. Older adults with BPPV should also be monitored for falls. Future studies with better methodological quality are needed to further investigate and address the above-discussed problems in younger and older adults with BPPV.

Clinical Messages

- ❑ Despite successful repositioning maneuvers, a moderate proportion of patients experienced incomplete recovery of some impairment outcomes.
- ❑ There is a need for serial assessment of BPPV signs and symptoms, gait, balance, and mental health outcomes for BPPV patients, and prescription of specific treatment for domains identified as outside normal limits.
- ❑ Older age may be associated with poorer dynamic balance recovery and increased self-perceived level of handicap. Future studies should further investigate and address these issues.

Acknowledgments

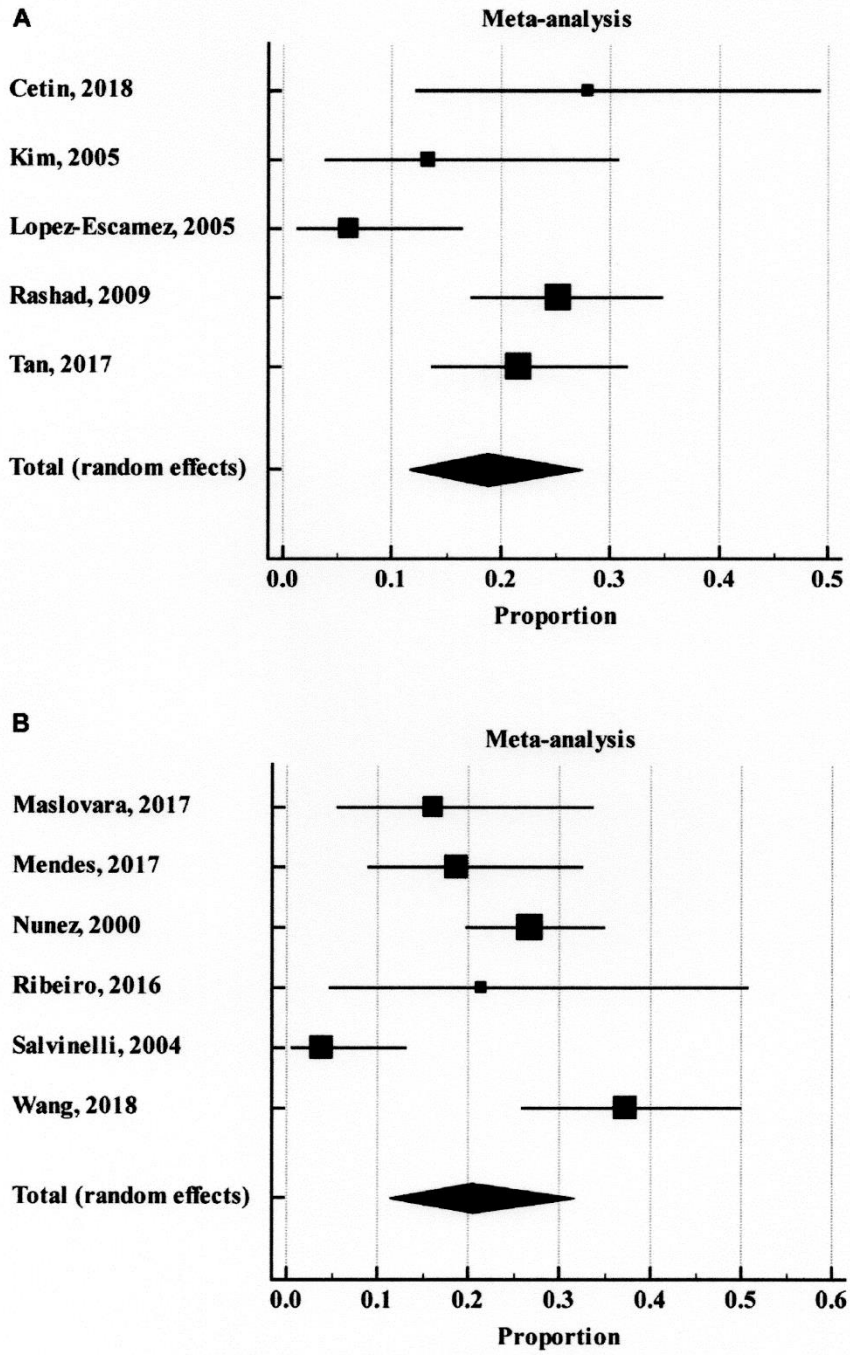
The authors would like to thank Edwin Lim, PhD, Assistant Professor, Singapore Institute of Technology, for his kind guidance.

References

1. Smouha E. Inner ear disorders. NeuroRehabilitation 2013;32:455–462.
2. 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.
3. Fife TD, Iverson DJ, Lempert T, et al. Practice parameter: Therapies for benign paroxysmal positional vertigo (an evidence-based review): Report of the quality standards subcommittee of the American academy of neurology. Neurology 2008;70:2067–2074.
4. Reinink H, Wegner I, Stegeman I, Grolman W. Rapid systematic review of repeated application of the Epley maneuver for treating posterior BPPV. Otolaryngol Head Neck Surg 2014;151:399–406.
5. Anagnostou E, Kouzi I, Spengos K. Diagnosis and treatment of anterior-canal benign paroxysmal positional vertigo: A systematic review. J Clin Neurol 2015;11:262–267.
6. Chen Y, Zhuang J, Zhang L, et al. Short-term efficacy of Semont maneuver for benign paroxysmal positional vertigo: A double-blind randomized trial. Otol Neurotol 2012;33:1127–1130.
7. Kinne BL, Strace CL, Crouch NA. The effectiveness of current interventions in the management of lateral canal benign paroxysmal positional vertigo. Phys Ther Rev 2012;17:292–300.
8. Abou-Elew MH, Shabana MI, Selim MH, et al. Residual postural instability in benign paroxysmal positional vertigo. Audiol Med 2011;9:8–15.
9. Di Girolamo S, Paludetti G, Briglia G, et al. Postural control in benign paroxysmal positional vertigo before and after recovery. Acta Oto-Laryngol 1998; 118:289–293.
10. Pollak L, Segal P, Stryjer R, Stern HG. Beliefs and emotional reactions in patients with benign paroxysmal positional vertigo: A longitudinal study. Am J Otolaryngol 2012;33:221–225.
11. Seok JI, Lee HM, Yoo JH, Lee DK. Residual dizziness after successful repositioning treatment in patients with benign paroxysmal positional vertigo. J Clin Neurol 2008;4:107–110.
12. Teggi R, Quaglieri S, Gatti O, et al. Residual dizziness after successful repositioning maneuvers for idiopathic benign paroxysmal positional vertigo. ORL J Otorhinolaryngol Relat Spec 2013;75:74–81.
13. Beynon GJ, Baguley DM, Da Cruz MJ. Recurrence, of symptoms following treatment of posterior semicircular canal benign positional paroxysmal vertigo with a particle repositioning maneuver. J Otolaryngol 2000;29:2–6.
14. Pérez P, Franco V, Cuesta P, et al. Recurrence of benign paroxysmal positional vertigo. Otol Neurotol 2012;33:437–443.
15. Babac S, Djeric D, Petrovic-Lazic M, et al. Why do treatment failure and recurrences of benign paroxysmal positional vertigo occur? Otol Neurotol 2014; 35:1105–1110.
16. Blatt PJ, Georgakakis GA, Herdman SJ, et al. The effect of the canalith repositioning maneuver on resolving postural instability in patients with benign paroxysmal positional vertigo. Am J Otol 2000;21:356–363.
17. Teggi R, Giordano L, Bondi S, et al. Residual dizziness after successful repositioning maneuvers for idiopathic benign paroxysmal positional vertigo in the elderly. Eur Arch Otorhinolaryngol 2011;268:507–511.
18. Kasse CA, Santana GG, Branco-Barreiro FC, et al. Postural control in older patients with benign paroxysmal positional vertigo. Otolaryngol Head Neck Surg 2012;146:809–815.

19. Vaz DP, Gazzola JM, Lanca SM, et al. Clinical and functional aspects of body balance in elderly subjects with benign paroxysmal positional vertigo. Braz J Otorhinolaryngol 2013;79:150–157.
20. Pollak L, Kushnir M, Shpirer Y, et al. Approach to benign paroxysmal positional vertigo in old age. Isr Med Assoc J 2005;7:447–450.
21. Bisdorff AR, Staab JP, Newman-Toker DE. Overview of the international classification of vestibular disorders. Neurol Clin 2015;33:541–550.vii.
22. Bisdorff A, Von Brevern M, Lempert T, Newman-Toker DE. Classification of vestibular symptoms: Towards an international classification of vestibular disorders. J Vestib Res 2009;19:1–13.
23. Bhattacharyya N, Gubbels SP, Schwartz SR, et al. Clinical practice guideline: Benign paroxysmal positional vertigo (update). Otolaryngol Head Neck Surg 2017;156(3 suppl):S1–S47.
24. The Joanna Briggs Institute. Joanna Briggs Institute Reviewers' Manual: 2014 edition. Adelaide, Australia: The Joanna Briggs Institute; 2014.
25. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann Intern Med 2009;151:264–269.w64.
26. Ribeiro KM, Ferreira LM, Freitas RV, et al. Positive to negative Dix-Hallpike test and benign paroxysmal positional vertigo recurrence in elderly undergoing canalith repositioning maneuver and vestibular rehabilitation. Int Arch Otorhinolaryngol 2016;20:344–352.
27. Ribeiro KM, Freitas RV, Ferreira LM, et al. Effects of balance vestibular rehabilitation therapy in elderly with benign paroxysmal positional vertigo: A randomized controlled trial. Disabil Rehabil 2017;39:1198–1206.
28. Chang W, Yang Y, Hsu L, et al. Balance improvement in patients with benign paroxysmal positional vertigo. Clin Rehabil 2008;22:338–347.
29. Cohen HS, Kimball KT. Effectiveness of treatments for benign paroxysmal positional vertigo of the posterior canal. Otol Neurotol 2005;26:1034–1040.
30. Gamiz MJ, Lopez-Escamez JA. Health-related quality of life in patients over sixty years old with benign paroxysmal positional vertigo. Gerontology 2004;50:82–86.
31. Giacomini PG, Alessandrini M, Magrini A. Long-term postural abnormalities in benign paroxysmal positional vertigo. ORL J Otorhinolaryngol Relat Spec 2002; 64:237–241.
32. Hoseinabadi R, Pourbakht A, Yazdani N, et al. The effects of abnormality of cVEMP and oVEMP on rehabilitation outcomes in patients with idiopathic benign paroxysmal positional vertigo. Eur Arch Otorhinolaryngol 2016;273:643–648.
33. Kahraman SS, Arli C, Copoglu US, et al. The evaluation of anxiety and panic agarophobia scores in patients with benign paroxysmal positional vertigo on initial presentation and at the follow-up visit. Acta Oto-Laryngol 2017;137:485–489.
34. Khatri M, Raizada RM, Puttewar MP. Epley's canalith-repositioning maneuver for benign paroxysmal positional vertigo. Ind J Otolaryngol Head Neck Surg 2005;57:315–319.
35. Kim EJ, Oh SY, Kim JS, et al. Persistent otolith dysfunction even after successful repositioning in benign paroxysmal positional vertigo. J Neurol Sci 2015;358: 287–293.
36. Kim YK, Shin JE, Chung JW. The effect of canalith repositioning for anterior semicircular canal canalithiasis. ORL J Otorhinolaryngol Relat Spec 2005;67:56–60.
37. Kollén L, Bjerlemo B, Möller C. Evaluation of treatment in benign paroxysmal positional vertigo (BPPV). Adv Physiother 2006;8:106–115.
38. Lopez-Escamez JA, Gamiz MJ, Fernandez-Perez A, Gomez-Finana M. Long-term outcome and health-related quality of life in benign paroxysmal positional vertigo. Eur Arch Otorhinolaryngol 2005;262:507–511.
39. Lopez-Escamez JA, Gomez Fiñana M, Fernandez AJ, et al. Impact of treatment on benign positional vertigo-related quality of life. Int Congress Series 2003; 1240:1329–1332.
40. Maslovara S, Soldo SB, Puksec M, et al. Benign paroxysmal positional vertigo (BPPV): Influence of pharmacotherapy and rehabilitation therapy on patients' recovery rate and life quality. NeuroRehabilitation 2012;31:435–441.
41. Mujeeb M, Khan NUH. Epley's maneuver: Treatment of choice for benign paroxysmal positional vertigo. J Laryngol Otol 2000;114:844–847.
42. Nunez RA, Cass SP, Furman JM. Short- and long-term outcomes of canalith repositioning for benign paroxysmal positional vertigo. Otolaryngol Head Neck Surg 2000;122:647–653.
43. Ouchterlony D, Masanic C, Michalak A, et al. Treating benign paroxysmal positional vertigo in the patient with traumatic brain injury: Effectiveness of the canalith repositioning procedure. J Neurosci Nurs 2016;48:90–99. quiz E1.
44. Prokopakis E, Vlastos IM, Tsagournisakis M, et al. Canalith repositioning procedures among 965 patients with benign paroxysmal positional vertigo. Audiol Neurotol 2013;18:83–88.
45. Prokopakis EP, Chimona T, Tsagournisakis M, et al. Benign paroxysmal positional vertigo: 10-year experience in treating 592 patients with canalith repositioning procedure. Laryngoscope 2005;115:1667–1671.
46. Rashad UM. Long-term follow up after Epley's maneuver in patients with benign paroxysmal positional vertigo. J Laryngol Otol 2009;123:69–74.
47. Salvinelli F, Trivelli M, Casale M, et al. Treatment of benign positional vertigo in the elderly: A randomized trial. Laryngoscope 2004;114:827–831.
48. Sato G, Sekine K, Matsuda K, Takeda N. Risk factors for poor outcome of a single Epley maneuver and residual positional vertigo in patients with benign paroxysmal positional vertigo. Acta Oto-Laryngol 2013;133:1124–1127.
49. Sekine K, Imai T, Sato G, et al. Natural history of benign paroxysmal positional vertigo and efficacy of Epley and Lempert maneuvers. Otolaryngol Head Neck Surg 2006;135:529–533.
50. Sridhar S, Panda N, Raghunathan M. Efficacy of particle repositioning maneuver in BPPV: A prospective study. Am J Otolaryngol 2003;24:355–360.
51. Yimtae K, Srirompotong S, Sae-Seaw P. A randomized trial of the canalith repositioning procedure. Laryngoscope 2003;113:828–832.
52. 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. Pak J Med Sci 2018;34:558–563.
53. Jozefowicz-Korczynska M, Pajor A, Skora W. Benign paroxysmal positional vertigo in patients after mild traumatic brain injury. Adv Clin Exp Med 2018; 27:1355–1359.
54. Kaur J, Shamanna K. Management of benign paroxysmal positional vertigo: A comparative study between Epleys manouvre and Betahistine. Int Tinnitus J 2017;21:30–34.
55. Maslovara S, Butkovic Soldo S, Sestak A, et al. 25 (OH) D3 levels, incidence and recurrence of different clinical forms of BPPV. Braz J Otorhinolaryngol 2018;84: 453–459.
56. Mendes T, Maslovara S, Vceva A, Soldo SB. Role of vestibular evoked myogenic potentials as an indicator of recovery in patients with benign paroxysmal positional vertigo. Acta Clin Croat 2017;56:756–764.
57. Tan J, Deng Y, Zhang T, Wang M. Clinical characteristics and treatment outcomes for benign paroxysmal positional vertigo comorbid with hypertension. Acta Oto-Laryngol 2017;137:482–484.
58. Wang Y, Xia F, Wang W, Hu W. Assessment of sleep quality in benign paroxysmal positional vertigo recurrence. Int J Neurosci 2018;1–7.
59. Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: Reference values and determinants. Age Ageing 1997;26:15–19.
60. Choy NL, Brauer S, Nitz J. Changes in postural stability in women aged 20 to 80 years. J Gerontol A Biol Sci Med Sci 2003;58:525–530.
61. Davalos-Bichara M, Agrawal Y. Normative results of healthy older adults on standard clinical vestibular tests. Otol Neurotol 2014;35:297–300.
62. Garratt AM, Stavem K. Measurement properties and normative data for the Norwegian SF-36: Results from a general population survey. Health Qual Life Outcomes 2017;15:51.
63. Gerolimatos LA, Edelstein BA. Predictors of health anxiety among older and young adults. Int Psychogeriatr 2012;24:1998–2008.
64. Lim KB, Lee HJ. Computerized posturographic measurement in elderly women with unilateral knee osteoarthritis. Ann Rehabil Med 2012;36:618–626.
65. Schmidheiny A, Swanenburg J, Straumann D, et al. Discriminant validity and test re-test reproducibility of a gait assessment in patients with vestibular dysfunction. BMC Ear Nose Throat Disord 2015;15:6.
66. Vereeck L, Wuyts F, Truijen S, Van de Heyning P. Clinical assessment of balance: Normative data, and gender and age effects. Int J Audiol 2008;47: 67–75.
67. Park H, Jung T. Limits of Stability, Tandem Walk, and Adaptation Test in individuals with symptomatic knee osteoarthritis: A case-control comparison with knee OA and healthy knee controls. Int J Hum Mov Sports Sci 2018;6: 23–29.
68. Nyenhuis DL, Yamamoto C, Luchetta T, et al. Adult and geriatric normative data and validation of the profile of mood states. J Clin Psychol 1999;55: 79–86.
69. Review Manager (RevMan) [Computer program]. 5.3 ed. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration; 2014.
70. **Lowry R. Estimation of a Sample's Mean and Variance from Its Median and Range 1998-2018. Available at:** http://vassarstats.net/median_range.html. **Accessed October 31, 2018.**
71. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 2005;5:13.
72. MedCalc Statistical Software. 18.10.2 ed. Ostend, Belgium: MedCalc Software bvba; 2018.
73. Freeman MF, Tukey JW. Transformations related to the angular and the square root. Ann Math Stat 1950;21:607–611.
74. Giommetti G, Lapenna R, Panichi R, et al. Residual dizziness after successful repositioning maneuver for idiopathic benign paroxysmal positional vertigo: A review. Audiol Res 2017;7:178.
75. Kao CL, Hsieh WL, Chern CM, et al. Clinical features of benign paroxysmal positional vertigo (BPPV) in Taiwan: Differences between young and senior age groups. Arch Gerontol Geriatr 2009;49(suppl 2):S50–S54.
76. Chang WC, Hsu LC, Yang YR, Wang RY. Balance ability in patients with benign paroxysmal positional vertigo. Otolaryngol Head Neck Surg 2006;135: 534–540.
77. Oliva Domínguez M, Bartual Magro J, Dañino González JL, et al. Postural control related to age in patients with benign positional paroxysmal vertigo. Acta Otorrinolaringol Esp 2005;56:354–360.
78. Gazzola JM, Gananca FF, Aratani MC, et al. Circumstances and consequences of falls in elderly people with vestibular disorder. Braz J Otorhinolaryngol 2006; 72:388–392.

Appendix



Appendix Figure 1. (A) Forest plot showing results of studies in the younger adult (<60 y old) group for recurrence. (B). Forest plot showing results of studies in the older adult (≥60 y old) group for recurrence.

Appendix Table 1
Search Strategy Adapted for PubMed

1. Benign Paroxysmal Positional Vertigo [MeSH] OR Benign Paroxysmal Positional Vertigo OR BPPV OR BPV
2. Adult* OR patient* OR older p* OR person* OR geriatric*
3. (repositioning man*) OR (canalith repositioning) OR (particle repositioning) OR (epley man*) OR (semont man*) OR (lempert man*) OR (gufoni man*) OR (appiani man*) OR (casani man*)
4. outcome* OR (treatment failure*) OR result* OR vertigo OR dizz* OR imbalance OR unstead* OR (poor balance) OR (postural instability) OR anxi* OR depress* OR (mental health)
5. 1 AND 2 AND 3 AND 4

Appendix Table 2
Meta-analysis of Proportion of BPPV Recurrence in the Younger Adult Group

Study	Events	Proportion (%)	95% CI	Weight (%)
				Random
(Younger Adult Group)				
Cetin, 2018	7/25	28.000	12.072-49.388	14.98
Kim, 2005	4/30	13.333	3.755-30.722	16.36
Lopez-Escamez, 2005	3/50	6.000	1.255-16.548	20.16
Rashad, 2009	26/103	25.243	17.199-34.759	24.69
Tan, 2017	19/88	21.591	13.528-31.645	23.82
Total (random effects)	59/296	18.816	11.499-27.445	100.00
Test for heterogeneity				
Q	**DF**	**Significance level**	**I^2 (inconsistency)**	**95% CI for I^2**
11.8385	4	$P = .0186$	66.21%	11.94-87.04
(Older Adult Group)				
Maslovara, 2017	5/31	16.129	5.452-33.727	15.49
Mendes, 2017	9/48	18.750	8.950-32.629	17.20
Nunez, 2000	37/138	26.812	19.633-35.014	19.89
Ribeiro, 2016	3/14	21.429	4.658-50.798	11.68
Salvinelli, 2004	2/52	3.846	0.469-13.213	17.48
Wang, 2018	25/67	37.313	25.797-49.990	18.27
Total (random effects)	81/350	20.543	11.328-31.652	100.00
Test for heterogeneity				
Q	**DF**	**Significance level**	**I^2 (inconsistency)**	**95% CI for I^2**
25.9504	5	$P = .0001$	80.73%	58.48-91.06

CI, confidence interval; DF, degrees of freedom.

Appendix B. Attribution Statement

Poor Treatment Outcomes following Repositioning Manoeuvres in Younger and Older Adults with Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis

Contributor	Statement of contributions
Eyvonne Sim	Conceptualisation and design of study (40%) Acquisition/Extraction of data (100%) Quality appraisal of studies (40%) Led draft and revisions of manuscript (40%)
Dawn Tan	Conceptualisation and design of study (30%) Quality appraisal of studies (30%) Critical revision of manuscript (30%) Study supervision (50%)
Keith Hill	Conceptualisation and design of study (30%) Quality appraisal of studies (30%) Critical revision of manuscript (30%) Study supervision (50%)

Appendix C. Copyright Statement

I have permission to include my published article (Poor Treatment Outcomes following Repositioning Manoeuvres in Younger and Older Adults with Benign Paroxysmal Positional Vertigo: A Systematic Review and Meta-analysis; published in the *Journal of the American Medical Directors Association*, 20(2), 224.e221-224.e223, doi: https://doi.org/10.1016/j.jamda.2018.11.019) in my thesis as the author for my personal use. The copyright of the article belongs to Elsevier.

Extracted from Elsevier's copyright information available online at https://www.elsevier.com/about/policies/copyright:

Author rights	Use and share their works for scholarly purposes (with full acknowledgement of the original article): 1. In their own classroom teaching. Electronic and physical distribution of copies is permitted 2. If an author is speaking at a conference, they can present the article and distribute copies to the attendees 3. Distribute the article, including by email, to their students and to research colleagues who they know for their personal use 4. Share and publicize the article via Share Links, which offers 50 days' free access for anyone, without signup or registration 5. Include in a thesis or dissertation (provided this is not published commercially) 6. Share copies of their article privately as part of an invitation-only work group on commercial sites with which the publisher has a hosting agreement
Institution rights	Theses and dissertations which contain embedded final published articles as part of the formal submission can be posted publicly by the awarding institution with DOI links back to the formal publication on ScienceDirect

Appendix D. Vestibular Rehabilitation Benefits Questionnaire (VRBQ) Scoring Template

(Morris et al., 2009)

Available at http://resource.isvr.soton.ac.uk/audiology/vrbq.htm.

Vestibular Rehabilitation Benefit Questionnaire

Scoring template

(for manual scoring photocopy template onto transparency and place over completed questionnaire)

Part A – your symptoms This section is about how often you experience different feelings.							Scores (office use)
1. I feel dizzy							
6	5	4	3	2	1	0	D
2. I get a feeling of tingling, prickling or numbness in my body							
6	5	4	3	2	1	0	A
3. I have a feeling that things are spinning or moving around							
6	5	4	3	2	1	0	D
4. I feel as though my heart is pounding or fluttering							
6	5	4	3	2	1	0	A
5. I feel unsteady, as though I may lose my balance							
6	5	4	3	2	1	0	D
6. I have difficulty breathing or feel short of breath							
6	5	4	3	2	1	0	A
This section is about how dizzy you get when you move around. Please do not circle 'not at all dizzy' if you avoid making the movement - either try the movement or talk to your balance therapist before answering.							
7. Bending over makes me feel							
0	1	2	3	4	5	6	M
8. Lying down and/or turning over in bed makes me feel							
0	1	2	3	4	5	6	M
9. Looking up at the sky makes me feel							
0	1	2	3	4	5	6	M
10. Moving my head <u>slowly</u> from side to side makes me feel							
0	1	2	3	4	5	6	M
11. Moving my head <u>quickly</u> from side to side makes me feel							
0	1	2	3	4	5	6	M

Part B – how the dizziness is affecting you

Please read each question carefully - some of the statements are phrased to suggest that you have difficulty (for example, 'I have trouble focusing my eyes') and some are phrased to suggest you do not have difficulty (for example, 'I feel comfortable travelling').

If a question does not apply to you, please circle 'same as before' rather than leaving it out.

	Scores (office use)
12. Compared to before the dizziness, I feel comfortable travelling −6 −4 −2 0 2 4 6	Q
13. Compared to before the dizziness, I feel confident −6 −4 −2 0 2 4 6	Q
14. Compared to before the dizziness, I have difficulty looking after myself (for example, washing my hair, cleaning my teeth, dressing myself, etc) 6 4 2 0 −2 −4 −6	14. reverse scoring Q
15. Compared to before the dizziness, I feel comfortable going out alone −6 −4 −2 0 2 4 6	Q
16. Compared to before the dizziness, I can concentrate and/or remember things −6 −4 −2 0 2 4 6	Q
17. Compared to before the dizziness, I need to hold on to something for support 6 4 −2 0 −2 −4 −6	17. reverse scoring Q
18. Compared to before the dizziness, I think my quality of life is good −6 −4 −2 0 2 4 6	Q
19. Compared to before the dizziness, I avoid some activities, positions or situations 6 4 −2 0 −2 −4 −6	19. reverse scoring Q
20. Compared to before the dizziness, I am happy to be on my own −6 −4 −2 0 2 4 6	Q
21. Compared to before the dizziness, I feel stable in the dark or when my eyes are closed −6 −4 −2 0 2 4 6	Q
22. Compared to before the dizziness, I take part in social activities −6 −4 −2 0 2 4 6	Q

Summary scores	Raw score	% deficit†
Symptoms Sum scores in boxes labelled D, A and M	(0 to 66)	raw x 1.52 =
Quality of Life Sum scores in boxes labelled Q	(0 to 66)‡	raw x 1.52 =
Total Sum Quality of Life and Symptom scores	(0 to 132)	raw x 0.76 =

Symptom subscales	Raw score	% deficit†
Dizziness Sum scores in boxes labelled D	(0 to 18)	raw x 5.56 =
Anxiety Sum scores in boxes labelled A	(0 to 18)	raw x 5.56 =
Motion-provoked dizziness Sum scores in boxes labelled M	(0 to 30)	raw x 3.34 =

† The percentage deficit quantifies the discrepancy between the respondent's state at the time of completing the questionnaire and their normal state. A deficit of 0% means no discrepancy is registered by the questionnaire; 100% is the maximum discrepancy the questionnaire can reflect.

‡ If the Quality of Life raw score is less than 0, raise to 0.

Appendix E. The Activities-specific Balance Confidence Scale (ABC)

(Powell & Myers, 1995)

Available at https://strokengine.ca/wp-content/uploads/2020/08/ABC-Scale-Instructions-updated-Oct-23-2020.pdf.

Activities-specific Balance Confidence (ABC) Scale/平衡信心指数问卷

Physiotherapy may help to improve balance problems. These questions will help your physiotherapist understand your confidence in maintaining your balance and help plan your treatment. For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the options on the scale form from 0% to 100%. If you do not currently do the activity in question, try to imagine how confident you would be if you had to do it. If you normally use a walking aid to do the activity or hold onto someone, rate as if you were using these supports.

物理治疗可以帮助改进平衡问题。以下的问题能够协助您的物理治疗师了解您在保持平衡方面的自信程度，以便更好地规划您的治疗方案。在进行以下的活动项目时， 您有信心维持平衡吗？请将您对以下的活动项目由 0%- 100% 打个信心分数。若有任何活动不在您的日常生活里， 试着想像您在进行这些活动。 如果您在这些活动里须用任何拐杖或它人的扶持，请一样地为自己打个信心指数。若有对问卷有任何疑问， 不妨向您的治疗师查询。谢谢。

"How confident are you that you will not lose your balance or become unsteady when you…"

“我在做这项活动时，我有_____%能维持平衡。”

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	No confidence 没有自信											**Fully confident 非常有自信**
1	…walk around the house? 在房间里散步											
2	…walk up or down stairs? 上下楼梯											
3	…bend over and pick up a slipper from the front of a closet floor 弯腰到地上捡起一双鞋子											
4	…reach for a small can off a shelf at eye level? 在与我一样高的架子上拿东西											

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	No confidence 没有自信											Fully confident 非常有自信
5	...stand on your tiptoes and reach for something above your head? 踮起腳, 在比我高的地方拿东西											
6	···stand on a chair and reach for something? 站在凳子上拿东西											
7	···sweep the floor? 扫地											
8	···walk outside the house to a car parked in the driveway? 外出搭乘交通工具											
9	···get into or out of a car? 上下交通工具											
10	···walk across a parking lot to the mall? 穿过停车场去商场											
11	···walk up or down a ramp? 走上或走下短的斜坡											
12	···walk in a crowded mall where people rapidly walk past you? 一个人到拥挤的商场去, 周围的人走得很快											
13	···are bumped into by people as you walk through the mall? 在拥挤的商场里, 被人撞了一下											
14	··· step onto or off an escalator while you are holding onto a railing? 拉着扶手, 上下自动扶梯											

		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	No confidence 没有自信											**Fully confident 非常有自信**
15	… step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? 手里拿着东西, 不能握住扶手, 上下自动扶梯											
16	…walk outside on icy sidewalks? 在湿滑的路面上行走											

Overall Score: _____ / 16 = _____%

Appendix F. The Human Activity Profile (HAP)

Human Activity Profile (Current)

*假如过去一年中您实际做过这一活动，那么才能在第 1 栏（“仍然在做这一活动”）中打勾	***Still doing this activity*** 仍然在做这一活动	***Have stopped doing the activity*** 已经停止这一活动	***Never did this activity*** 从未做过这一活动
1. Getting in and out of chairs or bed (without assistance) 坐入椅子，从椅子中站起或者上床下床（无人协助）			
2. Listening to the radio 听收音机			
3. Reading books, magazines, or newspapers 阅读书籍，杂志或报纸			
4. Writing (letters, notes) 书写（信件，笔记）			
5. Working at a desk or table 在写字台或桌子上工作			
6. Standing (for more than one minute) 站立（超过一分钟）			
7. Standing (for more than five minutes) 站立（超过五分钟）			
8. Dressing or undressing (without assistance) 穿衣或脱衣（无人协助）			
9. Getting clothes from drawers or closets 从抽屉或衣柜中拿衣服			
10. Getting in and out of a car (without assistance) 上车或下车（无人协助）			
11. Dining at a restaurant 在餐馆吃饭			
12. Playing cards/table games 玩牌/桌上游戏			
13. Taking a bath (no assistance needed) 洗盆浴（无人协助）			
14. Putting of shoes, stockings or socks (no rest or break needed) 穿上鞋，长统袜或短袜（中途不休息）			
15. Attending a movie, play, church event, or sports activity 去看电影，戏剧，上教堂或参加体育活动			
16. Walking 30 yards (27 metres) 行走 30 码（27 米）			
17. Walking 30 yards (non stop) 行走 30 码（中途不停）			
18. Dressing/undressing (no rest or break required) 穿衣/脱衣（中途不休息）			
19. Using public transport or driving a car (99 miles or less; 160 km or less)			

*假如过去一年中您实际做过这一活动，那么才能在第 1 栏（“仍然在做这一活动”）中打勾	***Still doing this activity*** 仍然在做这一活动	***Have stopped doing the activity*** 已经停止这一活动	***Never did this activity*** 从未做过这一活动
用公共交通或驾车（99 英里或少于此数; 160 公里或少于此数）			
20. Using public transport or driving a car (100 miles or more; 161 km or more) 使用公共交通或驾车（100 英里或高于此数; 161 公里或高于此数）			
21. Cooking your own meals 给自己做饭			
22. Washing or drying dishes 盥洗或擦干碗碟			
23. Putting groceries on shelves 将食品杂货放到架上			
24. Ironing or folding clothes 熨烫或折叠衣服			
25. Dusting/polishing furniture or polishing a car 给家具除尘/擦亮家具或擦亮汽车			
26. Showering 洗淋浴			
27. Climbing 6 steps 爬六个台阶			
28. Climbing 6 steps (non stop) 爬六个台阶（中途不停）			
29. Climbing 9 steps 爬九个台阶			
30. Climbing 12 steps 爬十二个台阶			
31. Walking ½ block on level ground 在水平地面步行半个街区			
32. Walking ½ block on level ground (non stop) 在水平地面步行半个街区（中途不停）			
33. Making a bed (not changing the sheets) 铺床（不换床单）			
34. Cleaning the windows 清洁窗户			
35. Kneeling or squatting to do light work 跪下或蹲下做轻活			
36. Carrying a light load of groceries 拿重量很轻的食品杂货			
37. Climbing 9 steps (non stop) 爬九个台阶（中途不停）			
38. Climbing 12 steps (non stop) 爬十二个台阶（中途不停）			
39. Walking ½ block uphill 上坡走半个街区			
40. Walking ½ block uphill (non stop) 上坡走半个街区（中途不停）			

*假如过去一年中您实际做过这一活动，那么才能在第 1 栏（“仍然在做这一活动”）中打勾	***Still doing this activity*** 仍然在做这一活动	***Have stopped doing the activity*** 已经停止这一活动	***Never did this activity*** 从未做过这一活动
41. Shopping (by yourself) 购物（自己进行）			
42. Washing clothes (by Yourself) 洗衣服（自己进行）			
43. Walking 1 block on level ground 在水平地面步行一个街区			
44. Walking 2 blocks on level ground 在水平地面步行两个街区			
45. Walking 1 block on level ground (non stop) 在水平地面步行一个街区（中途不停）			
46. Walking 2 blocks on level ground (non stop) 在水平地面步行两个街区（中途不停）			
47. Scrubbing (floors, walls, or cars) 擦洗（地板，墙壁或汽车）			
48. Making a bed (changing the sheets) 铺床（换床单）			
49. Sweeping 扫地			
50. Sweeping (five minutes non stop) 扫地（五分钟，中途不停）			
51. Carrying a large suitcase or bowling (one game) 拿一个大箱子或打保龄球（一条线）			
52. Vacuuming the carpets 地毯吸尘			
53. Vacuuming the carpets (non stop) 地毯吸尘（五分钟，中途不停）			
54. Painting (interior/exterior) 涂漆（室内/室外）			
55. Walking 6 blocks on level ground 在水平地面步行六个街区			
56. Walking 6 blocks on level ground (non stop) 在水平地面步行六个街区（中途不停）			
57. Carrying out the garbage 拿出垃圾			
58. Carrying a heavy load of groceries 拿重量很重的食品杂货			
59. Climbing 24 step 爬 24 个台阶			
60. Climbing 36 steps 爬 36 个台阶			
61. Climbing 24 steps (non stop) 爬 24 个台阶（中途不停）			

*假如过去一年中您实际做过这一活动，那么才能在第 1 栏（“仍然在做这一活动”）中打勾	***Still doing this activity*** 仍然在做这一活动	***Have stopped doing the activity*** 已经停止这一活动	***Never did this activity*** 从未做过这一活动
62. Climbing 36 steps (non stop) 爬 36 个台阶（中途不停）			
63. Walking 1 mile (1.6 km) 步行一英里 (1.6 公里)			
64. Walking 1 mile (non stop) 行走一英里（中途不停）			
65. Running 110 yards (100 meters) or playing softball/baseball 跑步 110 码（100 米）或玩垒球/篮球			
66. Dancing (social) 跳舞（社交性的）			
67. Doing callisthenics or aerobic dancing (5 minutes non stop) 做健美体操或需氧健身舞蹈（5 分钟、中途不停）			
68. Mowing the lawn (power mower, but not a riding mower) 割草（动力割草机，不是乘坐式割草机）			
69. Walking 2 miles (3.2 km) 步行两英里 (3.2 公里)			
70. Walking 2 miles (non stop) 行走两英里（中途不停）			
71. Climbing 50 steps (2.5 floors) 爬 50 个台阶			
72. Shovelling, digging, or spading 铲，挖			
73. Shovelling, digging, or spading (5 minutes non stop) 铲、挖（5 分钟、中途不停）			
74. Climbing 50 steps (non stop) 爬 50 个台阶（中途不停）			
75. Walking three miles (4.8 km) or golfing 18 holes without a riding cart 行走三英里(4.8 公里)或者不坐车打 18 洞的高尔夫球			
76. Walking 3 miles (4.8 km) (non stop) 行走三英里 (4.8 公里)（中途不停）			
77. Swimming 25 yards (23 meters) 游泳 25 码 （23 米）			
78. Swimming 25 yards (non stop) 游泳 25 码（中途不停）			
79. Bicycling 1 mile (1.6 km) 骑自行车一英里 (1.6 公里)			
80. Bicycling 2 miles (3.2 km) 骑自行车两英里 (3.2 公里)			
81. Bicycling 1 mile (1.6 km) (non stop) 骑自行车一英里 (1.6 公里)（中途不停）			
82. Bicycling 2 miles (3.2 km) (non stop) 骑自行车两英里 (3.2 公里)（中途不停）			
83. Running or jogging ¼ mile (400 meters) 跑跑步或慢跑¼英里 (400 米)			

*假如过去一年中您实际做过这一活动，那么才能在第 1 栏（“仍然在做这一活动”）中打勾	***Still doing this activity*** 仍然在做这一活动	***Have stopped doing the activity*** 已经停止这一活动	***Never did this activity*** 从未做过这一活动
84. Running or jogging ½ mile (800 meters) 跑步或慢跑½英里 (800 米)			
85. Playing tennis or racquetball 打网球或手球式壁球			
86. Playing basketball/soccer (game play) 打篮球（比赛）			
87. Running or jogging ¼ mile (400 meters) (non stop) 跑步或慢跑¼英里 (400 米)（中途不停）			
88. Running or jogging ½ mile (800 meters) (non stop) 跑步或慢跑½英里 (800 米)（中途不停）			
89. Running or jogging 1 mile (1.6 km) 跑步或慢跑一英里 (1.6 公里)			
90. Running or jogging 2 miles (3.2 km) 跑步或慢跑两英里 (3.2 公里)			
91. Running or jogging 3 miles (4.8 km) 跑步或慢跑三英里 (4.8 公里)			
92. Running or jogging 1 mile (1.6 km) in 12 minutes or less 在 12 分钟或更短时间内跑步或慢跑一英里 (1.6 公里)			
93. Running or jogging 2 miles (3.2 km) in 20 minutes or less 在 20 分钟或更短时间内跑步或慢跑两英里(3.2 公里)			
94. Running or jogging 3 miles (4.8 km) in 30 minutes or less 在 30 分钟或更短时间内跑步或慢跑三英里(4.8 公里)			

HAPMAS = ……. HAPAAS = …….

References:

1. *Daughton DM, Fix AJ, Kass I, Bell CW, Patil KD. Maximum oxygen consumption and the ADAPT quality-of-life scale. Arch Phys Med Rehabil. 1982;63(12):620-2.*
2. *Bonner A, Wellard S, Kenrick M. Development and validation of the Human Activity Profile into Chinese language: lessons in determining equivalence. Nursing & health sciences. 2006 Mar 1;8(1):36-43.*

Appendix G. The 15-Item Geriatric Depression Scale (GDS-15)

15-item Geriatric Depression Scale (GDS-15)

Choose the best answer for how you have felt over the past week.

以下的问题是人们对一些事物的感受。 在过去一星期内，如果你曾有以下的感受，请在“是”✓。如果没有的话，请在“否”✓

		Yes 是	No 否
1	Are you basically satisfied with your life? 你对自己的生活基本上满意吗？		
2	Have you dropped many of your activities and interests? 你是否已放弃了自己的很多活动和兴趣？		
3	Do you feel that your life is empty? 你是否觉得生活空虚？		
4	Do you often get bored? 你是否常常感到无聊？		
5	Are you in good spirits most of the time? 你是否常常感到精神不错，精神还可以？		
6	Are you afraid that something bad is going to happen to you? 你是否害怕会有不好的事情发生在你身上呢？		
7	Do you feel happy most of the time? 你大部分时间心情还可以吗？		
8	Do you often feel helpless? 你是否经常觉得无助？		
9	Do you prefer to stay at home, rather than going out and doing new things? 你是否宁愿留在家里，而不外出并做些新的事呢？		
10	Do you feel you have more problems with memory than most? 你是否觉得你的记忆力比多数人差？		
11	Do you think it is wonderful to be alive now? 你是否觉得活着真好，活着还不错？		
12	Do you feel pretty worthless the way you are now? 你是否觉得自己现在很没用呢？		
13	Do you feel full of energy? 你是否感到精力充足，精力足够应付日常的生活？		
14	Do you feel that your situation is hopeless? 你是否觉得自己的处境没有希望？		
15	Do you think that most people are better off than you are? 你是否觉得多数人都比你活得好吗？		

Total score: _____.

References:

1. *Sheikh JI, Yesavage JA: Geriatric Depression Scale (GDS): Recent evidence and development of a shorter version. Clinical Gerontology: A Guide to Assessment and Intervention 165-173, NY: The Haworth Press, 1986.*
2. *The Australian Chinese translation was developed as part of a study conducted by the National Ageing Research Institute (NARI), Australia. Website: http://www.nari.net.au/*

Appendix H. The Geriatric Anxiety Inventory (GAI)

Geriatric Anxiety Inventory

Please answer the items according to how you've felt in the last week.

Tick the column under Agree if you mostly agree that the item describes you; tick the column under Disagree if you mostly disagree that the item describes you.

请根据最近一周内您的感受对下列题目作答。如果您基本同意题目对您的描述，请在“同意”下的圆圈上划“√”，如果基本不同意题目对您的描述，请在“不同意”下的圆圈上划“√”

	Agree 同意	Disagree 不同意
I worry a lot of the time. 我经常在担忧。		
I find it difficult to make a decision. 我觉得我做出决定有困难。		
I often feel jumpy. 我经常觉得坐立不安。		
I find it hard to relax. 我觉得很难放松下来。		
I often cannot enjoy things because of my worries. 我经常因为担忧而不能享受生活乐趣。		
Little things bother me a lot. 一点小事也会让我感到很烦恼。		
I often feel like I have butterflies in my stomach. 我经常感到胃里抖动不适。		
I think of myself as a worrier. 我觉得自己是个容易担忧的人。		
I can't help worrying about even trivial things. 即使一点小事也会让我不由自主地担忧。		
I often feel nervous. 我经常感到紧张。		
My own thoughts often make me anxious. 我自己的想法经常让我焦虑。		
I get an upset stomach due to my worrying. 我的担忧经常使我感到胃部难受。		
I think of myself as a nervous person. 我认为自己是个紧张兮兮的人。		

	Agree 同意	Disagree 不同意
I always anticipate the worst will happen. 我总是预感最坏的事情会发生。		
I often feel shaky inside. 我经常觉得体内颤抖。		
I think that my worries interfere with my life. 我觉得我的担忧干扰了我的生活。		
My worries often overwhelm me. 我经常被自己的担忧压倒。		
I sometimes feel a great knot in my stomach. 我有时感觉胃抽筋得厉害。		
I miss out on things because I worry too much. 我会因为担忧过度而错失一些事物。		
I often feel upset. 我经常感到心烦。		

Original GAI reference: Pachana, N.A., Byrne, G.J., Siddle, H., Koloski, N., Harley. E., & Arnold, E. (2007). Development and validation of the Geriatric Anxiety Inventory. International Psychogeriatrics, 19, 103-114.

Appendix I. Email correspondence from the UniQuest eShop for the use of Geriatric Anxiety Inventory (GAI) in this thesis

Eyvonne Siew Siean Sim

From: Anne Bannister <a.bannister@uniquest.com.au>
Sent: Tuesday, 12 July 2016 12:51 PM
To: Eyvonne Siew Siean Sim
Subject: FW: Your Order From UniQuest eShop (#491)
Attachments: Final Journal Article.pdf; GAI MATERIALS LICENSE - NON COMMERCIAL USE.pdf; GAI new English-UK.pdf; GAI Scoring Information_FINAL.pdf; GAI new Chinese-Singapore.pdf

Dear Eyvonne,

Many thanks for your interest in the Geriatric Anxiety Inventory.

Attached is a copy of the GAI (English -UK) and GAI (CHN – SIN) and the scoring information, along with the journal article and a copy of the license terms and conditions that you agreed to on the UniQuest e-shop.

Regards
Anne

From: eShop Orders
Sent: Monday, 27 June 2016 8:10 PM
To: GAI Orders <GAI_Orders@uniquest.com.au>
Subject: FW: Your Order From UniQuest eShop (#491)

From: UniQuest eShop
Sent: Monday, 27 June 2016 8:09:44 PM (UTC+10:00) Brisbane
To: eShop Orders
Subject: Fwd: Your Order From UniQuest eShop (#491)

Thank you for your Order

Your order ID is **#491**.

Shipping Address

Eyvonne Sim
3 Canberra Drive #12-05 One Canberra
Singapore, 768102
Singapore
+65 97615213

Billing Address

Eyvonne Sim
3 Canberra Drive #12-05 One Canberra
Singapore, 768102
Singapore
+65 97615213

Your Order Contains...

Cart Items	Qty	Item Price	Item Total
GAI form - (Chinese language - SIN) - Non-Commercial Use First name of applicant: Eyvonne	1	$0.00 AUD	**$0.00 AUD**

1

Surname of applicant:	Sim
Email address:	e.sim@postgrad.curtin.edu.au
Confirm your email address:	e.sim@postgrad.curtin.edu.au
Name of research or academic institution:	Curtin University of Technology
Website for research or academic institution:	http://www.curtin.edu.au/
Street address of research or academic institution:	Kent Street, Bentley, Perth Western Australia 6102
Country of research or academic institution:	Australia
Description of intended research or academic or other non-commercial use of GAI:	The GAI is intended for use in my PhD (Physio) stu ..

GAI form - (English language - GBR) - Non-Commercial Use				
First name of applicant:	Eyvonne			
Surname of applicant:	Sim			
Email address:	e.sim@postgrad.curtin.edu.au			
Confirm your email address:	e.sim@postgrad.curtin.edu.au			
Name of research or academic institution:	Curtin University of Technology			
Website for research or academic institution:	http://www.curtin.edu.au/	1	$0.00 AUD	**$0.00 AUD**
Street address of research or academic institution:	Kent Street, Bentley, Perth Western Australia 6102			
Country of research or academic institution:	Australia			
Description of intended research or academic or other non-commercial use of GAI:	The GAI is intended for use in my PhD (Physio) stu ..			

Subtotal:	**$0.00 AUD**
Shipping:	**$0.00 AUD**

Grand Total: **$0.00 AUD**

UniQuest eShop
http://eshop.uniquest.com.au/

Appendix J. The Dynamic Gait Index (DGI)

(Anne Shumway-Cook & Woollacott, 1995)

Available at *https://www.physio-pedia.com/Dynamic_Gait_Index*.

DGI Items	Score
1. Gait level surface *Instructions:* Walk at your normal speed from here to the next mark (20') *Grading:* Mark the lowest category that applies. (3) Normal: Walks 20', no assistive devices, good sped, no evidence for imbalance, normal gait pattern (2) Mild Impairment: Walks 20', uses assistive devices, slower speed, mild gait deviations. (1) Moderate Impairment: Walks 20', slow speed, abnormal gait pattern, evidence for imbalance. (0) Severe Impairment: Cannot walk 20' without assistance, severe gait deviations or imbalance.	
2. Change in gait speed *Instructions:* Begin walking at your normal pace (for 5'), when I tell you "go," walk as fast as you can (for 5'). When I tell you "slow," walk as slowly as you can (for 5'). *Grading:* Mark the lowest category that applies. (3) Normal: Able to smoothly change walking speed without loss of balance or gait deviation. Shows a significant difference in walking speeds between normal, fast and slow speeds. (2) Mild Impairment: Is able to change speed but demonstrates mild gait deviations, or not gait deviations but unable to achieve a significant change in velocity, or uses an assistive device. (1) Moderate Impairment: Makes only minor adjustments to walking speed, or accomplishes a change in speed with significant gait deviations, or changes speed but has significant gait deviations, or changes speed but loses balance but is able to recover and continue walking. (0) Severe Impairment: Cannot change speeds, or loses balance and has to reach for wall or be caught.	

DGI Items	Score
3. Gait with horizontal head turns *Instructions:* Begin walking at your normal pace. When I tell you to "look right," keep walking straight, but turn your head to the right. Keep looking to the right until I tell you, "look left," then keep walking straight and turn your head to the left. Keep your head to the left until I tell you "look straight," then keep walking straight, but return your head to the center. *Grading:* Mark the lowest category that applies. (3) Normal: Performs head turns smoothly with no change in gait. (2) Mild Impairment: Performs head turns smoothly with slight change in gait velocity, i.e., minor disruption to smooth gait path or uses walking aid. (1) Moderate Impairment: Performs head turns with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk. (0) Severe Impairment: Performs task with severe disruption of gait, i.e., staggers outside 15" path, loses balance, stops, reaches for wall.	
4. Gait with vertical head turns *Instructions:* Begin walking at your normal pace. When I tell you to "look up," keep walking straight, but tip your head up. Keep looking up until I tell you, "look down," then keep walking straight and tip your head down. Keep your head down until I tell you "look straight," then keep walking straight, but return your head to the center. *Grading:* Mark the lowest category that applies. (3) Normal: Performs head turns smoothly with no change in gait. (2) Mild Impairment: Performs head turns smoothly with slight change in gait velocity, i.e., minor disruption to smooth gait path or uses walking aid. (1) Moderate Impairment: Performs head turns with moderate change in gait velocity, slows down, staggers but recovers, can continue to walk. (0) Severe Impairment: Performs task with severe disruption of gait, i.e., staggers outside 15" path, loses balance, stops, reaches for wall.	
5. Gait and pivot turn *Instructions:* Begin walking at your normal pace. When I tell you, "turn and stop," turn as quickly as you can to face the opposite direction and stop. *Grading:* Mark the lowest category that applies. (3) Normal: Pivot turns safely within 3 seconds and stops quickly with no loss of balance. (2) Mild Impairment: Pivot turns safely in > 3 seconds and stops with no loss of balance. (1) Moderate Impairment: Turns slowly, requires verbal cueing, requires several small steps to catch balance following turn and stop. (0) Severe Impairment: Cannot turn safely, requires assistance to turn and stop.	

DGI Items	Score
6. Step over obstacle *Instructions:* Begin walking at your normal speed. When you come to the shoebox, step over it, not around it, and keep walking. *Grading:* Mark the lowest category that applies. (3) Normal: Is able to step over the box without changing gait speed, no evidence of imbalance. (2) Mild Impairment: Is able to step over box, but must slow down and adjust steps to clear box safely. (1) Moderate Impairment: Is able to step over box but must stop, then step over. May require verbal cueing. (0) Severe Impairment: Cannot perform without assistance.	
7. Step around obstacles *Instructions:* Begin walking at normal speed. When you come to the first cone (about 6' away), walk around the right side of it. When you come to the second cone (6' past first cone), walk around it to the left. *Grading:* Mark the lowest category that applies. (3) Normal: Is able to walk around cones safely without changing gait speed; no evidence of imbalance. (2) Mild Impairment: Is able to step around both cones, but must slow down and adjust steps to clear cones. (1) Moderate Impairment: Is able to clear cones but must significantly slow, speed to accomplish task, or requires verbal cueing. (0) Severe Impairment: Unable to clear cones, walks into one or both cones, or requires physical assistance.	
8. Steps *Instructions:* Walk up these stairs as you would at home, i.e., using the railing if necessary. At the top, turn around and walk down. *Grading:* Mark the lowest category that applies. (3) Normal: Alternating feet, no rail. (2) Mild Impairment: Alternating feet, must use rail. (1) Moderate Impairment: Two feet to a stair, must use rail. (0) Severe Impairment: Cannot do safely.	

Total score: ___ / 24

Appendix K. SingHealth Centralised Institutional Review Board (CIRB) Approval Letter

This is the initial ethics approval by SingHealth CIRB. Subsequent approvals were obtained for revisions to the protocol and study forms.

SingHealth
Defining Tomorrow's Medicine

Tel: (65) 6225 0488
Fax: (65) 6557 2138
Singapore Health Services Pte Ltd
31 Third Hospital Avenue
#03-03 Bowyer Block C
Singapore 168753
www.singhealth.com.sg
UEN No. 200002698Z

CIRB Ref: **2016/2799**

3 November 2016

Dr Tan May Leng Dawn
Department of Physiotherapy
Singapore General Hospital

Dear Dr Tan

SINGHEALTH CENTRALISED INSTITUTIONAL REVIEW BOARD (CIRB) APPROVAL

Protocol Title: Post Treatment Dizziness, Vertigo and Imbalance in Older Adults with Benign Paroxysmal Positional Vertigo: Prevalence, Predictors and Personal Experiences.

We are pleased to inform you that the SingHealth CIRB F has approved the above research project to be conducted in Singapore General Hospital.

The documents reviewed are:

a) CIRB Application Form dated 25 Oct 2016
b) Study Protocol: Version 1 dated 19 Sep 2016
c) Participant Information Sheet and Consent Form: Version 1 dated 14 Sep 2016
d) Consent for Video Recording: Version 1 dated 29 Aug 2016
e) Data Collection Form: English Version 1 dated 22 Sep 2016
f) Study Flowchart and Schedule: Version 1 dated 19 Sep 2016
g) Falls Calendar: English Version 1 dated 29 Aug 2016
h) Short Survey (Indepth Interview): Version 1 dated 29 Aug 2016
i) Short Survey (Patient Survey): Version 1 dated 27 Aug 2016
j) Screening Form: Version 1 dated 19 Sep 2016
k) Treatment Log: Version 1 dated 21 Sep 2016
l) Prospective Falls Log: Version 1 dated 21 Sep 2016

The SingHealth CIRB operates in accordance with the ICH/ Singapore Guideline for Good Clinical Practices, and with the applicable regulatory requirement(s).

The approval period is from **3 November 2016 to 17 October 2017**. The reference number for this study is CIRB Ref: 2016/2799. Please use this reference number for all future correspondence.

The SingHealth CIRB acknowledges receipt of the following translated documents:
i. Chinese Data Collection Form: Version 1 dated 22 Sep 2016
ii. Chinese Falls Calendar: Version 1 dated 29 Aug 2016

Please ensure that the translations are an accurate reflection of the original content approved by SingHealth CIRB.

Kindly note that the SingHealth CIRB accepts the authenticity of the translations based on the translation certificates, if any, provided by the Principal Investigator. Consequently, it is the responsibility of the Principal Investigator to ensure that the translations are an accurate reflection of the original approved content.

This study shall not commence until the legal framework for compensation has been agreed and signed by all parties.

The following are to be observed upon SingHealth CIRB Approval:

1. No subject should be admitted to the trial before the Health Sciences Authority issues the Clinical Trial Certificate. (only applicable for drug-related studies).

2. The Principal Investigator should ensure that this study is conducted in compliance with the Singapore Guideline for Good Clinical Practice, the ethical guidelines of which are applicable to all studies to be carried out, and to ensure that the study is carried out in accordance to the guidelines and the submitted protocol. The Principal Investigator should meet with his collaborator(s) regularly to assess the progress of the study, and be familiar and comply with all applicable research policies in the Institution.

3. No deviation from, or changes of, the protocol should be initiated without prior written SingHealth CIRB approval of an appropriate amendment, except when necessary to eliminate immediate hazards to the subjects or when the change(s) involve(s) only logistical or administrative aspects of the trial (e.g. change of monitor(s), telephone number(s).

4. Only the approved Participant Information Sheet and Consent Form should be used. It must be signed by each subject prior to enrolling in the study and initiation of any protocol procedures. Two copies of the Informed Consent Form should be signed and dated. Each subject or the subject's legally accepted representative should be given a copy of the signed consent form. The remaining copy should be kept by the PI / medical record.

5. The Principal Investigator should report promptly to the SingHealth CIRB of:
    i. Deviations from, or changes to the protocol including those made to eliminate immediate hazards to the trial subjects.
    ii. Changes increasing the risk to subjects and/or affecting significantly the conduct of the trial.
    iii. All serious adverse events (SAEs) and adverse drug reaction (ADRs) that are both serious and unexpected.
    iv. New information that may affect adversely the safety of the subjects or the conduct of the trial.
    v. Completion of the study.

6. Study Status Report should be submitted to the SingHealth CIRB for the following:
    i. Annual review: Status of the study should be reported to the SingHealth CIRB at least annually using the Study Status Report.
    ii. Study renewal: the Study Status Report is to be submitted at least two months prior to the expiry of the approval period. A valid SingHealth CIRB renewal is essential, as any research performed outside of an approved time frame is not legal, and thus not covered by the hospital's research insurance in case of unexpected adverse reactions.

iii. Study completion or termination: the Final Report is to be submitted within three months of study completion or termination.

Yours sincerely,

Dr Aloysius Ho Yew Leng
Chairman
SingHealth Centralised Institutional Review Board F

Enc.

cc: Institution Representative, SGH
Head, Department of Physiotherapy, SGH

This application is approved online. No signature is required.

Appendix L. Curtin University Human Research Ethics Committee (HREC) Approval Letter

This is the initial ethics approval by the Curtin University HREC. Subsequent approvals were obtained for revisions to the protocol and study forms.

Curtin University

Office of Research and Development

GPO Box U1987
Perth Western Australia 6845

Telephone +61 8 9266 7863
Facsimile +61 8 9266 3793
Web research.curtin.edu.au

09-Jan-2017

Name: Keith Hill
Department/School: School of Physiotherapy and Exercise Science
Email: Keith.Hill@curtin.edu.au

Dear Keith Hill

RE: Reciprocal ethics approval
Approval number: HRE2017-0008

Thank you for your application submitted to the Human Research Ethics Office for the project Post Treatment Dizziness, Vertigo and Imbalance in Older adults with Benign Paroxysmal Positional Vertigo: Prevalence, Predictors and Personal Experiences..

Your application has been approved by the Curtin University Human Research Ethics Committee (HREC) through a reciprocal approval process with the lead HREC.

The lead HREC for this project has been identified as SingHealth Centralised Institutional Review Board (Singapore).

Approval number from the lead HREC is noted as 2016/2799.

The Curtin University Human Research Ethics Office approval number for this project is **HRE2017-0008**. Please use this number in all correspondence with the Curtin University Ethics Office regarding this project.

Approval is granted for a period of one year from **09-Jan-2017** to **08-Jan-2018**. Continuation of approval will be granted on an annual basis following submission of an annual report.

Personnel authorised to work on this project:

Name	Role
Hill, Keith	CI
Sim, Eyvonne Siew Sean	Co-Inv
Tan, Dawn	Co-Inv
Pua, Yong Hao	Co-Inv

You must comply with the lead HREC's reporting requirements and conditions of approval. You must also:

- Keep the Curtin University Ethics Office informed of submissions to the lead HREC, and of the review outcomes for those submissions
- Conduct your research according to the approved proposal

- Report to the lead HREC anything that might warrant review of the ethics approval for the project
- Submit an annual progress report to the Curtin University Ethics Office on or before the anniversary of approval, and a completion report on completion of the project. These can be the same reports submitted to the lead HREC.
- Personnel working on this project must be adequately qualified by education, training and experience for their role, or supervised
- Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, that bears on this project
- Data and primary materials must be managed in accordance with the Western Australian University Sector Disposal Authority (WAUSDA) and the Curtin University Research Data and Primary Materials policy
- Where practicable, results of the research should be made available to the research participants in a timely and clear manner
- The Curtin University Ethics Office may conduct audits on a portion of approved projects.

This letter constitutes ethical approval only. This project may not proceed until you have met all of the Curtin University research governance requirements.

Should you have any queries regarding consideration of your project, please contact the Ethics Support Officer for your faculty or the Ethics Office at hrec@curtin.edu.au or on 9266 2784.

Yours sincerely

Professor Peter O'Leary
Chair, Human Research Ethics Committee

Appendix M. The Participant Information Sheet and Consent Form (PICF) (version 6, 14 February 2019)

This is the most updated version of the PICF.

SingHealth

Curtin University

PARTICIPANT INFORMATION SHEET AND CONSENT FORM

STUDY INFORMATION

Protocol Title:

Post Treatment Dizziness, Vertigo and Imbalance in Older adults with Benign Paroxysmal Positional Vertigo: Prevalence, Predictors and Personal Experiences.

Principal Investigator:

Dr Dawn Tan
Senior Principal Physiotherapist
Department of Physiotherapy, Singapore General Hospital
Address: National Heart Centre Building Level 7 SGH Rehabilitation Centre
Contact number: +65 8125 2985

Research Support:

This research is supported by Curtin University (Australia) and the SGH Research Grant – New Investigator Grant (SRG-NIG) grant.

PURPOSE OF THE RESEARCH STUDY

You are being invited to participate in a research study. Before you take part in this research study, the study must be explained to you and you must be given the chance to ask questions. Please read carefully the information provided here. If you agree to participate, please sign the consent form. You will be given a copy of this document to take home with you.

You are being invited to participate in a research study on older adults with Benign Paroxysmal Positional Vertigo (BPPV). BPPV is a condition that affects the inner ear and may cause one to experience spinning and/or falling sensations when the head is in a specific position or movement.

The aims of this study are to:

1) Learn about the possible factors that influence good and poor outcomes.
2) Learn about the long-term outcomes of older adults with BBPV.
3) Learn about your experiences on how BPPV and its management impact on your daily activities and how you feel.

You are selected as a possible participant in this study because you fulfil the criteria for participation in this research study. This study aims to recruit a total of 108 participants with BPPV from the Singapore General Hospital, as well, as another 108 participants without BPPV.

STUDY PROCEDURES AND VISIT SCHEDULE

If you agree to take part in this study, you will be assigned to the BPPV or non-BPPV group, depending on the results of the BPPV test. You will be asked to go through the same assessment as all other participants. If you are assigned to the BPPV group, the assessment will be repeated at four different time points as listed under the "Schedule of visits". Your participation in the study will last for about seven months.

During the assessments, we will ask you some questions about your current health and past medical conditions. The research team will require access to your personal health records to obtain information about your medical condition. You will also be asked to complete some questionnaires which will help us to understand your condition better. Physical examination will include testing for BPPV as well as tests to check the function of the balance system in the inner ear. We will also be checking your walking and balance function. You might experience some discomfort and dizziness during certain tests, which is expected and normal, and will settle quickly. Do be assured we will take precautions and ensure your comfort and safety at all times during the tests. If you are unable to undergo or complete any assessment(s), or have any concerns, during the session, please let us know immediately. We will assess and take necessary actions to ensure your comfort and safety. You will also be asked to keep track of and record any falls you may have in the monthly falls diary, which can either be mailed back to or be collected by the study team,

If you have BPPV, you may be invited to undergo an interview session with one of our study team members. The purpose is to find out in detail how BPPV and the related treatment have affected the physical and emotional aspects of your life. The interview will be about an hour long and will take place in one of the consultation rooms at the Physiotherapy Outpatient Clinic in SGH. An audio recording of the interview will be taken to aid in accuracy of data collection.

Please note that you will not be required to undergo any medical or physiotherapy treatment for this research study. However, if you have BPPV, you will continue to receive treatment prescribed by your doctor and physiotherapist as part of your routine care at the Singapore General Hospital.

Schedule of visits and procedures

***For BPPV group:**

Visit 1: Coincides with your consultation with the doctor or physiotherapist; Undergo about 2 hours of assessment which includes questionnaires, BPPV, balance and walking tests.

Visit 2: One week after Visit 1. Undergo up to 3 hours of session (assessment and treatment) as with Visit 1.

Visit 3: One month after Visit 2. Undergo up to 3 hours of session (assessment and treatment) as with Visit 1 and an interview session (about 60 minutes).

Visit 4: Two months after Visit 3. Undergo up to 3 hours of session (assessment and treatment) as with Visit 1.

Final Visit: Three months after Visit 4. Undergo up to 3 hours of session (assessment and treatment) as with Visit 1.

Please note that should there be changes to your BPPV or functional status, additional assessment may be needed.

***For the non-BPPV group:**

Visit 1: Undergo about 2.5 hours of assessment which includes questionnaires, BPPV, balance and walking tests.

Subsequently for the next six months: No visits required. Continued monitoring of falls through completion of monthly falls diary, which can be mailed back to or be collected by one of our study team members. Alternatively, this may be followed up via phone calls.

Any individually-identifiable data obtained during the course of this study will be stored and used only for the purposes of this study. These data will not be used for future research.

YOUR RESPONSIBILITIES IN THIS STUDY

If you agree to participate in this study, you should:

- Keep to your study appointments. If it is necessary to miss an appointment, please contact the study team to reschedule as soon as you know you will miss the appointment.
- Be prepared to visit the hospital for up to 5 sessions and undergo all the procedures that are outlined above. To minimise inconvenience to you, the study assessment will be conducted on the same day as your hospital outpatient appointment where possible.
- Be diligent in the monitoring for falls and in completion of the monthly falls diaries as well as scheduled questionnaires (if any) and maintaining contact with the study team.

WHAT IS NOT STANDARD CARE OR EXPERIMENTAL IN THIS STUDY

Although the questionnaires and physical assessment items may be part of standard medical care, in this study, these procedures are being performed for the purposes of the research. The use of Wii Balance Board for balance assessment is done for the purpose of research.

If you are in the BPPV group, you will undergo treatment for BPPV. However, you should be aware that the treatment is included as part of the standard care and is NOT experimental and NOT part of this study.

POSSIBLE RISKS, DISCOMFORTS AND INCONVENIENCES

The assessment procedures are unlikely to have any side effects as these are standard tests commonly perform in clinical settings. If you have BPPV, you may experience short duration of dizziness from positioning tests commonly performed in the clinical settings to test for the presence of BPPV. As with any form of physical activity there are small but possible risks associated with participation. These risks include severe dizziness which does not resolve with rest, pain, fatigue or injury. Rest breaks will be provided throughout testing during the walking and balance tests to minimise these risks. The tests do not involve any invasive procedures.

Your medical history will be thoroughly screened, and the assessment sessions will be performed under the supervision of an experienced physiotherapist. You will be closely monitored for any adverse effects such as dizziness, pain, fatigue or other symptoms.

There may be additional risks that the researchers do not expect or do not know about. You will need to tell the study team immediately about any new or unusual symptoms.

POTENTIAL BENEFITS

There is no assurance you will benefit from this study. However, you will receive a thorough assessment of your balance and movement functions, which may benefit your ongoing rehabilitation or provide better insight into your current functional status.

Your participation will allow us to determine the possible contributing factors to good or poor outcomes in the treatment of BPPV. It will also give us new information on how these outcomes and factors might affect older adults in the long term. This research will help to improve our understanding on how to improve care for older adults with BPPV in the future.

ALTERNATIVES

If you have BPPV and are interested in the study but have concerns over the interview, you can discuss this further with the study team member. You may choose not to take part in the interview but still participate in the rest of the study. You may indicate your preference on page 6 of the informed consent form.

If you choose not to take part in this study and if you have BPPV, the alternative is to have

what is considered standard care for your condition. In our institution this would be the usual clinical walking and balance tests with the physiotherapist. There will be no monthly follow-up on falls or monitoring of BPPV and functional status.

This standard care has the usual benefits of a routine physiotherapy assessment and poses the same possible risks as associated with physical activity which includes dizziness, pain, fatigue or injury.

If you are unable to come for a follow-up session, arrangement can be made for us to do phone interview instead.

COSTS OF PARTICIPATION

If you take part in this study, the following will be performed at no charge to you:

- One to five sessions of 2-hour assessment of your balance and movement
- Repositioning treatment for BPPV for patients in the BPPV group
- Follow-up on falls for six months

In appreciation of your participation, you will receive $35 reimbursement, for each session that you complete

INCIDENTAL FINDINGS

During the course of the study, there is a possibility that we might unintentionally come to know of new information about your health condition from the physical assessments and questionnaires that is/are conducted as part of the study. These are called "incidental findings".

In the case of an "incidental finding" (i.e. any abnormality that we did not expect to see in this study or unrelated to the purpose of this study), we will not re-identify and give you any results from the research.

PARTICIPANT'S RIGHTS

Your participation in this study is entirely voluntary. Your questions will be answered clearly and to your satisfaction.

In the event of any new information becoming available that may be relevant to your willingness to continue in this study, you (or your legal representative, if relevant) will be informed in a timely manner by the Principal Investigator or his/her representative and will be contacted for further consent if required.

By signing and participating in the study, you do not waive any of your legal rights to revoke your consent and withdraw from the study at any time.

WITHDRAWAL FROM STUDY

You are free to withdraw your consent and discontinue your participation at any time without prejudice to you or effect on your medical care. If you decide to stop taking part in this study, please notify the Principal Investigator or a study team member.

If you withdraw from the study, the study team will not collect additional personal information from you, although personal information already collected will be retained to ensure that the results of the research project can be measured properly. You should be aware that data collected up to the time you withdraw will form part of the research project results. You will also have to return any study related materials you may have.

The Principal Investigator of this study may stop your participation in the study at any time for

one or more of the following reasons:

- Failure to follow the instructions of the Principal Investigator and/or study team member.
- The Principal Investigator decides that continuing your participation could be harmful.
- The study is cancelled.

RESEARCH RELATED INJURY AND COMPENSATION

If you follow the directions of the Principal Investigator of this research study and you are injured due to the trial substance or research procedure given under the plan for the research study, our institution will provide you with the appropriate medical treatment.

Payment for management of the normally expected consequences of your treatment will not be provided by the Singapore General Hospital. However, compensation by Curtin University (Australia) may be considered on a case-by-case basis for unexpected injuries related to the research.

You still have all your legal rights. Nothing said here about treatment or compensation in any way alters your right to recover damages where you can prove negligence.

CONFIDENTIALITY OF STUDY AND MEDICAL RECORDS

Information collected for this study will be kept confidential. Your records, to the extent of the applicable laws and regulations, will not be made publicly available. Only your Investigator(s) will have access to the confidential information being collected.

However, Regulatory Agencies, Institutional Review Board and Ministry of Health will be granted direct access to your original medical records to check study procedures and data, without making any of your information public.

By signing the Consent Form, you consent to (i) the collection, access to, use and storage of your Personal Data by Singapore General Hospital, and (ii) the disclosure of such Personal Data to our authorised service providers and relevant third parties.

Where required, such Future Studies will be submitted for review and necessary approval by the relevant institutional review board.

"Personal Data" means data about you which makes you identifiable (i) from such data or (ii) from that data and other information which an organisation has or is likely to have access. Examples of personal data include medical conditions, medications, investigations and treatment history.

By signing the Consent Form, you also confirm that you have read, understood and consented to the SingHealth Data Protection Policy, the full version of which is available at www.singhealth.com.sg/pdpa.

Data collected and entered into the Data Collection Form(s) are the property of Singapore General Hospital. In the event of any publication regarding this study, your identity will remain confidential.

All audio tapes will be stored under lock and key in the research cupboard of the SGH Physiotherapy Department. Soft copies of the audio recordings will be kept in an encrypted, password protected hard drive, which will also be stored in the research cupboard under lock and key. Only study team members will have access to the tapes and soft copies. All folders and documents will also be password protected.

WHO TO CONTACT IF YOU HAVE QUESTIONS REGARDING THE STUDY

If you have questions about this research study or in the case of any injuries during the

course of this study, you may contact the Principal Investigator or study team member:

Dr Dawn Tan (Principal Investigator)
Senior Principal Physiotherapist
Contact number: 81252985
SGH mainline: 62223322

Ms Eyvonne Sim (Co-Investigator)
PhD Candidate, Curtin University
Contact number: 97615213

WHO HAS REVIEWED THE STUDY

This study has been reviewed by the SingHealth Centralised Institutional Review Board for ethics approval.

If you have questions about your rights as a participant, you can call the SingHealth Centralised Institutional Review Board at 6323 7515 during office hours (8:30 am to 5:30pm).

If you have any feedback about this research study, you may contact the Principal Investigator or the SingHealth Centralised Institutional Review Board.

CONSENT FORM

Details of Research Study

Protocol Title:

Post Treatment Dizziness, Vertigo and Imbalance in Older adults with Benign Paroxysmal Positional Vertigo: Prevalence, Predictors and Personal Experiences.

Principal Investigator:

Dr Dawn Tan

Senior Principal Physiotherapist

Singapore General Hospital

Contact number: +65 8125 2985

I agree to participate in the research study as described and on the terms set out in the Participant Information Sheet.

I have fully discussed and understood the purpose and procedures of this study. I have been given the Participant Information Sheet and the opportunity to ask questions about this study and have received satisfactory answers and information.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reasons and without my medical care being affected.

By participating in this research study, I confirm that I have read, understood and consent to the SingHealth Data Protection Policy.

(For participants with BPPV only) I consent to be interviewed and I am aware that the interview will be audio recorded for data collection purpose:

□ ***Yes*** □ ***No*** □ ***Not applicable***

Name of participant	Signature/Thumbprint (Right / Left)	Date of signing

To be completed by parent / legal guardian / legal representative, where applicable

I hereby give consent for the above participant to participate in the proposed research study. The nature, risks and benefits of the study have been explained clearly to me and I fully understand them.

I confirm that I have read, understood and consent to the SingHealth Data Protection Policy.

Name of participant's parent/ legal guardian/ legal representative	Signature/ Thumbprint (Right / Left)	Date of signing

To be completed by translator, if required

The study has been explained to the participant/ legal representative in

_____ by _____.
Language Name of translator

To be completed by witness, where applicable

I, the undersigned, certify that:

- I am 21 years of age or older.
- To the best of my knowledge, the participant or the participant's legal representative signing this informed consent form had the study fully explained in a language understood by him/ her and clearly understands the nature, risks and benefits of his/ her participation in the study.
- I have taken reasonable steps to ascertain the identity of the participant or the participant's legal representative giving the consent.
- I have taken steps to ascertain that the consent has been given voluntarily without any coercion or intimidation.

Witnessed by: _____ _____
Name of witness Date of signing

_____
Signature of witness

1. An impartial witness (who is 21 years of age or older, has mental capacity, who is independent of the research study, and cannot be unfairly influenced by people involved with the research study) should be present during the entire informed consent discussion if a participant or the participant's legal representative is unable to read, and/or sign and date on the consent form (i.e. using the participant or legal representative thumbprint). After the written consent form and any written information to be provided to participant, is read and explained to the participant or the participant's legal representative, and after the participant or the participant's legal representative has orally consented to the participant's participation in the study and, if capable of doing so, has signed and personally dated the consent form, the witness should sign and personally date the consent form. This is applicable for Clinical Trials regulated by HSA and Human Biomedical Research under HBRA.

2. For HBRA studies, the witness may be a member of the team carrying out the research only if a participant or the participant's legal representative is able to read, sign and date on the consent form.

Investigator's Statement

I, the undersigned, certify to the best of my knowledge that the participant/ participant's legal representative signing this consent form had the study fully explained and clearly understands the nature, risks and benefits of his/ her/ his ward's/ her ward's participation in the study.

_____ _____ _____
Name of Investigator/ Person obtaining consent Signature Date

Appendix N. List of guiding interview questions used in the semi-structured interviews in the Qualitative Study (Chapter 7)

1. Would you share with me what you know about BPPV?

   Prompts: Causes / Signs and symptoms / Treatment / Pathomechanism (ear crystals dislodged in inner ear) / Life threatening? / Treatable?

2. How has BPPV affected you?
   (Alternate question: In what ways has BPPV affected you?)

   Prompts: Physical / Activities / Functional / Mood / Emotions / Social / Family / Work / Relationships / Life-style / Fear-avoidance

3. It has been one month since your first BPPV treatment. How has your condition changed so far?

   Prompts: Symptoms / Activities / Mobility / Balance / Confidence / Fear avoidance / Better / Worse / No change / Coping strategies

4. Have the changes met your expectation? Please elaborate.
   (Alternate question: How satisfied are you with these changes?)

   Prompts: what were your expectations?

5. How are you involved in the treatment and rehabilitation process?

   Prompts: Participation / Discussion / Opinions / Expectations / Respect / Decision making process / Empowerment

6. In your BPPV rehab journey so far, what do you think could have been done differently or better?

7. BPPV can occur again. What would you do if you suspect the problem has returned?

   Prompts: Recognition of BPPV symptoms / see the doctor or physiotherapist / tell difference between stroke and BPPV symptoms / medications / repositioning exercises if taught previously / previous advice given by doctor and physio