IMPROVING SCREENING AND PHYSIOTHERAPY MANAGEMENT OF VESTIBULAR DISORDERS IN THE HOSPITAL SETTING

Submitted by

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A thesis submitted in total fulfilment of the requirements of the degree

Doctor of Philosophy (PhD by publication)

School of Physiotherapy

Faculty of Health Sciences

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1100 Nudgee Rd, Banyo

Date of Submission: 11th June 2018

“Knowing is not enough, we must apply.

Willing is not enough, we must do.”

Goethe

Statement of Authorship

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degrees or diploma.

No parts of this thesis have been submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgement in the main test of the thesis.

All research procedures reported in the thesis received the approval of the relevant ethics / safety committee.

Assistance was sought by Dr Jennifer Peat and Dr Warren Stanton in the statistical analysis of the results. Assistance was limited to a teaching capacity in how to undertake the statistical analysis, rather than completing the analysis.

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Acknowledgments

I have been very fortunate to have Professor Nancy Low Choy as my primary supervisor. Nancy has expertise in research with a strong passion and vast knowledge on vestibular physiotherapy, an area that this thesis centres on. Nancy's guidance, patience, and timely feedback were perfectly balanced with giving me space to develop independence. Thank-you for your generosity with your time, your calm approach to teaching, and your phenomenal dedication to teaching and to our profession.

I have also been blessed to have Dr. Dilani Mendis as my supervisor. Dilani is dedicated to excellence in physiotherapy research and understands balancing work, study and family life. Thank-you for sharing your knowledge, constructive advice, and for dedicating your time and effort in making this thesis a reality.

A special acknowledgement and thanks to Dr. Suzanne Kuys for providing constructive and timely feedback, especially for the final stages of writing this thesis.

I would like to express gratitude to the following funding sources for making this possible:

- The Prince Charles hospital foundation
- Queensland rehabilitation physiotherapy network

- Allied health professions office of Queensland health practitioner research grant scheme

There are several individuals who have contributed to my positive PhD experience who I would like to thank:

- Susan Lewandowski for helping develop the vestibular service, sharing my research vision and for making data collection a reality.
- Jenny Peat for her assistance with statistical design and your patience in teaching statistical methods with SPSS, predominantly over the phone.
- Dr. Nicole Bellet, the Director of Physiotherapy and Gregory Morrison, Clinical lead of Rehabilitation at the Prince Charles hospital, for their continuous support and encouragement;
- Dr. Jeff Rowland and the consultants in the Internal Medicine team at the Prince Charles hospital for sharing my passion and vision for vestibular physiotherapy and for spreading the word.
- Alyssia Economidis and Carrie Bailey for assisting with data collection.
- The physiotherapy department, the internal medicine team and emergency department team of the Prince Charles hospital for enabling and supporting this research.

- Ian Parker, a fellow PhD candidate, for sharing a vision in developing vestibular physiotherapy services around the state and for being a great support in the PhD journey.
- My family, in particular my parents, who helped looked after my sons whilst I wrote the final chapters of this thesis.

Lastly I would like to thank my husband, Matthew Stewart. During my PhD candidature you allowed me to keep the challenges of research in perspective and never doubted my ability to complete the job at hand. Thank-you for balancing the many research hours with the wonderful life we share with our sons Frederick and Vincent.

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Publications included in this thesis

Stewart, V., Mendis, M.D., Low Choy, N. *A systematic review of patient-reported measures associated with vestibular dysfunction*. Laryngoscope, 2018. **128**: p. 971-981.

- Incorporated as Chapter 2, Section 2.9

Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. Concurrent validity and responsiveness to change of the Vestibular Screening Tool, to screen for vestibular disorders in the acute hospital setting. Otorinolaringologia, 2018. Manuscript in press.

- Incorporated as Chapter 4, Section 4.3

Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. *Construction and Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting.* Archives of Physical Medicine and Rehabilitation, 2015. **96**: p. 1253-1260.

- Incorporated as Chapter 4, Section 4.2

Grants awarded and presentations

Grants awarded

The candidate would like to express gratitude to the following funding sources for supporting this research program:

1. Stewart, V. (2013) Validation of a Vestibular Screening Tool in the acute hospital setting, in detecting vestibular disorder to facilitate referral of people to Physiotherapy Vestibular Clinic ($9,646), funded by the Prince Charles hospital foundation.
2. Stewart, V. (2013) Longer term outcomes from immediate and delayed (wait-list) service models to inform best practice for the Vestibular Rehabilitation Service at TPCH ($2,000), funded by Queensland Rehabilitation Physiotherapy Network.
3. Stewart, V., Low Choy, N., Economidis, A., Rowland, J., Mendis, D. (2014) Longer term outcomes from immediate and delayed (wait-list) service models to inform best practice for the Vestibular Rehabilitation Service at TPCH ($18,000), funded by Allied Health Research Grant Scheme.

Podium presentations

1. Stewart, V. (2013) Clinical Utility of a Vestibular Screening Tool to facilitate referral to Physiotherapy – Preliminary data. Neuro Otology of Australia (NOTSA) Conference (Melbourne), 18th October 2013.
2. Stewart, V. (2013) Clinical Utility of a Vestibular Screening Tool to facilitate referral to Physiotherapy – Preliminary findings. Queensland Rehabilitation Physiotherapy Network (QRPN) Conference (Brisbane), 29th November 2013.
3. Stewart, V (2014) Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting. Australian Catholic University higher degree research day (Brisbane), December 2014
4. Stewart, V. (2014) Validation of Vestibular Screening Tool for use in Emergency Department & Acute Hospital Setting. The Prince Charles hospital research forum (Brisbane), 30th October 2014.
5. Stewart, V. (2014) Validation of Vestibular Screening Tool for use in Emergency Department & Acute Hospital Setting. Queensland Rehabilitation Physiotherapy Network (QRPN) Conference (Brisbane), 28th November 2014.

6. Stewart, V (2015) Clinical effectiveness of a physiotherapy-led vestibular service in a tertiary setting. Neuro Otology of Australia (NOTSA) Conference (Melbourne), 18th September 2015.
7. Stewart, V (2015) Does the VST differentiate clinical presentations of patients referred to a Physiotherapy-led vestibular service in a tertiary hospital? Australian Physiotherapy Association Conference (Gold Coast), 5th October 2015.
8. Stewart, V (2015) Clinical effectiveness of a physiotherapy-led vestibular service in a tertiary hospital. Australian Catholic university higher degree research day (Brisbane), 29th September 2015.
9. Stewart, V (2016) Clinical effectiveness of a physiotherapy-led vestibular hospital service comparing immediate and delayed intervention pathways. Physical Medicine and Rehabilitation Conference (Philadelphia, United States of America), 24th – 26th August 2016.

Poster presentations

- Stewart, V., Mendis, MD., Low Choy, N. (2013) Validation of a Vestibular Screening Tool in the acute hospital setting to facilitate referral to the Physiotherapy Vestibular Clinic. The Prince Charles hospital annual research conference (Brisbane), 17th October 2013.

- Stewart, V., Mendis, MD., Low Choy, N. (2014) Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting, Neuro Otology of Australia (NOTSA) Conference (Sydney), 8-9th August 2014.
- Stewart, V., Mendis, MD., Low Choy, N. (2015) Concurrent validity of the vestibular screening tool with the dizziness handicap inventory, comparing acute and community presentations across three time-points, Australian Physiotherapy Association Conference (Gold Coast), 5th October 2015.

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Abstract

Vestibular disorders significantly impact a person's quality of life and daily function with symptoms such as dizziness, vertigo, visual disturbances and balance impairment. Vestibular disorders commonly cause hospital presentations and are often under diagnosed and therefore mis-managed in the emergency department (ED) and acute medical environment (AME). There is a lack of research assisting clinicians in identifying and managing vestibular disorders in these settings. There is also limited evidence concerning the effectiveness of a physiotherapy vestibular service in the acute hospital setting for managing non-emergent vestibular disorders (non-life threatening).

The primary aim of this thesis was to improve the service model of care (screening and physiotherapy clinical intervention) of people who present to hospital with non-emergent vestibular disorders. The sequence of studies involved in this research program were conducted as two phases and aimed to 1) construct and validate a new vestibular screening tool (VST) for use in the ED / AME to guide referral to physiotherapy vestibular rehabilitation; 2) determine the clinical effectiveness of a hospital based, physiotherapy-led vestibular service, and 3) compare an immediate physiotherapy intervention pathway with a delayed intervention pathway.

The background of the thesis highlights the high prevalence of vestibular disorders and contextualises the need for a clinical questionnaire to assist in the identification of such disorders in the ED / AME. The thesis includes a systematic review (Paper 1) demonstrating the lack of existing self-report questionnaires appropriate for use in the acute hospital setting. The systematic review utilised the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) checklist to test the quality of existing patient-reported measures / screening tools.

Phase one of the thesis includes the construction and validation of a new questionnaire, the VST, to guide referral to physiotherapy vestibular rehabilitation. The first paper of Phase one (Paper 2) describes a methodological study undertaken in the ED / AME of a metropolitan hospital with adults (N = 114) presenting to hospital with dizziness complaints. The construction of the VST was based on two longer questionnaires identified in the systematic review, the dizziness handicap inventory (DHI) and the vestibular rehabilitation benefit questionnaire. The Rasch measurement model was utilised to develop the construct validity of the VST; factor analysis demonstrated unidimensionality; whilst Cronbach α statistic identified internal consistency of the VST. Receiver operating characteristic curves tested three versions of the VST for sensitivity and specificity. The 4-item VST had the greatest area under the curve (.894) with highest sensitivity (83%) and specificity

(84%) for identifying non-emergent vestibular disorders (cut-off value ≥ 4 / 8). The VST showed high inter-rater and intra-rater reliability.

The next paper of Phase one (Paper 3), describes a longitudinal prospective study, undertaken with adults (N =195) presenting to hospital with non-emergent vestibular disorders. Physiotherapy vestibular diagnostic tests categorised people into vestibular or non-vestibular groups. The VST and DHI were completed concurrently at 3 time-points with participants who received vestibular rehabilitation intervention. The VST was found to have concurrent validity against the DHI, across the continuum of care. The VST also demonstrated responsiveness to change after vestibular rehabilitation intervention.

Phase two, which deals with investigating aims 2 and 3 of the thesis, includes a prospective observational study (Paper 4), which determined the immediate and longer-term clinical effectiveness of a new vestibular rehabilitation service within the hospital setting (N = 193). Baseline, discharge and follow-up outcomes were reported. Linear mixed models determined significance of the mean difference of measures across the continuum of care. People had significantly reduced dizziness / vertigo symptoms and significantly improved mobility at discharge, which was maintained 3-months post discharge ($p \leq 0.001$).

Recent research has suggested that early intervention of vestibular disorders is important. However, the best time to commence vestibular rehabilitation requires investigation. Therefore, Phase two (Paper 4) also tested the outcomes of people immediately referred to the physiotherapy vestibular service; compared to those referred through a waitlist, delayed pathway. Both immediate and delayed intervention groups reported significantly reduced dizziness / vertigo impairment ($p \leq 0.001$), but only the immediate group significantly improved in all mobility measures ($p \leq 0.005$). Resultant symptoms and functional impact of a vestibular disorder did not significantly subside to normal without vestibular rehabilitation, even 3-weeks after presenting to hospital.

The results of this thesis, including the construction and validation of the VST, may clinically assist with screening and therefore referral to physiotherapy vestibular services. The validation of the VST provides a clinically useful tool for a hospital setting. Findings from this research support the clinical effectiveness of a hospital-based physiotherapy vestibular service. Finally, results indicate immediate referral to physiotherapy vestibular services should be considered.

Abbreviations

ABC	Activities specific balance confidence scale
ABC-6	Activities specific balance confidence short form
AME	Acute medical environment
ANOVA	Analysis of variance
AUC	Area under the curve
BPPV	Benign paroxysmal positional vertigo
COSMIN	Consensus-based standards for the selection of health measurement instruments
DHI	Dizziness handicap inventory
ED	Emergency department
FGA	Functional gait assessment
HINTS	Head impulse, nystagmus, test of skew
HIT	Head impulse test
HPD	Hallpike-Dix
ICC	Intraclass correlation coefficient

MCID	Minimal clinically important difference
PRM	Particle repositioning manoeuvres
ROC	Receiver operating characteristic
TPCH	The Prince Charles hospital
TUG	Timed up and go
VADL	Vestibular disorders activities of daily living
VAP	Vestibular activities and participation
VDI	Vertigo, dizziness, imbalance
VHQ	Vertigo handicap questionnaire
VOR	Vestibular Ocular Reflex
VPT	Vestibular physiotherapy
VR	Vestibular rehabilitation
VRBQ	Vestibular rehabilitation benefit questionnaire
VSS	Vertigo symptom scale
VST	Vestibular screening tool
10MWT	10 metre walk test

Chapter 1 Introduction

Vestibular disorders are common clinical manifestations in the emergency department (ED) [1-3] and are an underlying cause of people complaining of dizziness [4]. Dizziness (umbrella term encompassing vertigo) reportedly accounts for roughly 4% of chief complaints in the ED [5]. Consequences of vestibular disorders are debilitating to the individual [6, 7] and costly to society [5, 8]. Vestibular disorders have been associated with falls [9], anxiety and depression [10], shown to impact mood and cognitive status [10], and negatively affect quality of life [11]. Costs associated with the management of vestibular disorders is also significant [5, 12]. Total US national costs are estimated to exceed $4 billion per year for people presenting to the ED with dizziness (about 4% of all ED costs) [5].

People with vestibular disorders presenting to ED are often not managed optimally [13]. Screening for vestibular disorders in adults presenting to ED with symptoms of dizziness and vertigo does not routinely occur. [4, 14]. There is a lack of research assisting clinicians in identifying and managing non-emergent vestibular disorders (non-life threatening) in the ED / acute medical environment (AME). Although physiotherapists are well positioned to assess and manage vestibular disorders, in the form of vestibular physiotherapy (VPT), to date, there is limited evidence concerning the effectiveness of a physiotherapy vestibular service in a hospital

setting. Additionally, there is a lack of research investigating the best time to commence VPT, and the effect of a delay to vestibular intervention (assessment and management) on clinical outcomes in people presenting to hospital with a vestibular disorder.

1.1 Scope of thesis

The broad aim of the thesis is to improve the service model of care (screening and management) for people presenting to hospital with a non-emergent vestibular disorder. To achieve the overall aim, the research program is detailed in two phases. The primary research aim of Phase one of this research program is to construct a valid and reliable screening tool to identify non-emergent vestibular disorders in the acute hospital setting. The primary research aim of Phase two of the research thesis is to determine clinical effectiveness and outcomes of people seen in a physiotherapy-led hospital-based vestibular service by determining short-term and longer-term outcomes after completing vestibular rehabilitation (VR). The second aim of Phase two, is to test the clinical outcomes of people immediately referred to the physiotherapy vestibular service; compared to those referred through a waitlist, delayed intervention pathway.

In order to investigate the aims of the thesis, limits to the research are required. The research is focused on the hospital setting. The hospital setting includes the ED and AME and out-patient physiotherapy clinics managing people who have been

discharged from hospital. In particular, the research focuses on adults with a non-emergent vestibular disorder as the underlying cause to their presentation to ED with dizziness complaints. It is also narrowed down to the emphasis on non-emergent vestibular disorders and excludes life-threatening, emergent disorders (potentially life threatening) such as stroke. The thesis additionally focuses on physiotherapy intervention of vestibular disorders, including the use of VPT. Overall intervention of vestibular disorders can include pharmacological, psychological, surgical interventions, and VPT. The focus of this research is the effectiveness of a physiotherapy-led vestibular service for adults with non-emergent vestibular disorders. There is need for these limitations because the investigation of the management of dizziness symptoms or vestibular disorders is a broad and complex area.

1.2 Overview of thesis

This thesis consists of six chapters, which are set out in the following way. In the background chapter (Chapter 2), the theoretical underpinnings of vestibular disorders are detailed with a critical review of the current assessment and treatment practices for vestibular disorders, as well as a review of available vestibular screening measures. In this regard, the first paper is presented (Paper 1), a systematic review of patient-reported questionnaires to determine appropriateness for use in ED / AME to screen for vestibular disorders. Chapter 2

argues the need for the development of a vestibular screening tool and the need for research investigating the clinical effectiveness of physiotherapy vestibular intervention in the hospital setting for vestibular disorders.

The 'Methodology and design' chapter (Chapter 3) details the principal research frameworks guiding the design underpinning Phase one and Phase two of the thesis. Rationale for the research protocol used in this thesis is presented followed by detailed discussion of the selection of measures for Phase one and Phase two of the research program.

Chapter 4 details the results for Phase one, which encompasses two research papers (Paper 2 and Paper 3). Papers for Phase one revolve around the validation of the vestibular screening tool (VST) in the hospital setting. Chapter 5 presents the results for Phase two, which are presented as a research paper (Paper 4). Paper 4 utilises the VST and addresses the clinical effectiveness of a hospital-based, physiotherapy-led vestibular service, comparing immediate / delayed intervention.

Chapter 6, 'Synthesis of findings, clinical implications and future research', provides an overview of significant findings of the thesis, including comparisons and contrasts with existing literature and the clinical implications of the research. Discussion on the limitations of the research program follows and a discussion of the directions for future research is included. A final concluding remark completes the thesis.

Chapter 2 Background

The purpose of the vestibular system is to provide a sense of balance and an awareness of spatial orientation. The vestibular system is first and foremost a sensory system. It detects head movement (acceleration) and head position. It uses that information to generate eye movements that assure gaze stability and postural responses. It also sends that information to other central nervous system structures for the perception of head movement and position and the integration of that information with other sensory inputs.

To understand the importance and direction that this thesis will take and to inform the methodology developed, this chapter will outline the anatomy, physiological functions, and symptoms of the vestibular system; detail the prevalence of dizziness, vertigo and vestibular disorders; establish the consequences of vestibular disorders and dizziness; present current understanding and classification of vestibular disorders; and detail the assessment and treatment of vestibular disorders.

To achieve the overall aim of this thesis, gaps in the literature need to be identified and specific aims for the studies in this thesis developed. The rationale for the need for a screening tool to aid referral to physiotherapy vestibular services will emerge through the systematic review of current questionnaires related to screening for

monitoring dizziness. The systematic review will examine the suitability of available questionnaires for use as a screening tool in the ED / AME to aid referral to physiotherapy services.

Another priority gap in the literature will be identified through this background chapter; the clinical effectiveness of a physiotherapy vestibular service in a hospital setting when people present to the ED / AME and are referred for immediate intervention or sent home with a referral to the out-patient VPT service (delayed intervention). This chapter will conclude with a discussion about the need for future research, which will inform the specific aims and hypotheses for this thesis.

2.1 Vestibular anatomy, physiological functions and symptoms

To understand vestibular disorders and the associated burden it causes, it is important to first outline the anatomy and physiology of the vestibular system. The role of the vestibular system is to detect motion of the head to allow stability of images on the fovea of the retina as well as allowing postural control during head motion [15].

A vestibular disorder is often referred to as 'otologic dizziness' or 'vestibular vertigo' [15]. Vertigo is due to an asymmetric disturbance of sensory input from the vestibular organs in the peripheral system or asymmetric integration of vestibular input into the central nervous system [15]. Vertigo is defined as 'the sensation of

self-motion when no self-motion is occurring or the sensation of distorted self-motion during an otherwise normal head movement' [16]. It is generally accepted that vertigo involves a spinning sensation [17].

2.1.1 Anatomy of the vestibular system

The vestibular system consists of a central component and a peripheral component. Central parts of the vestibular system include the vestibular nuclear complex, vestibule cerebellum, brainstem, spinal cord, and vestibular cortex. The peripheral vestibular system consists of semicircular canals, the otoliths (utricle and saccule), and the vestibular nerve (to the dorsal root entry zone) as seen in Figure 2-1 [18].

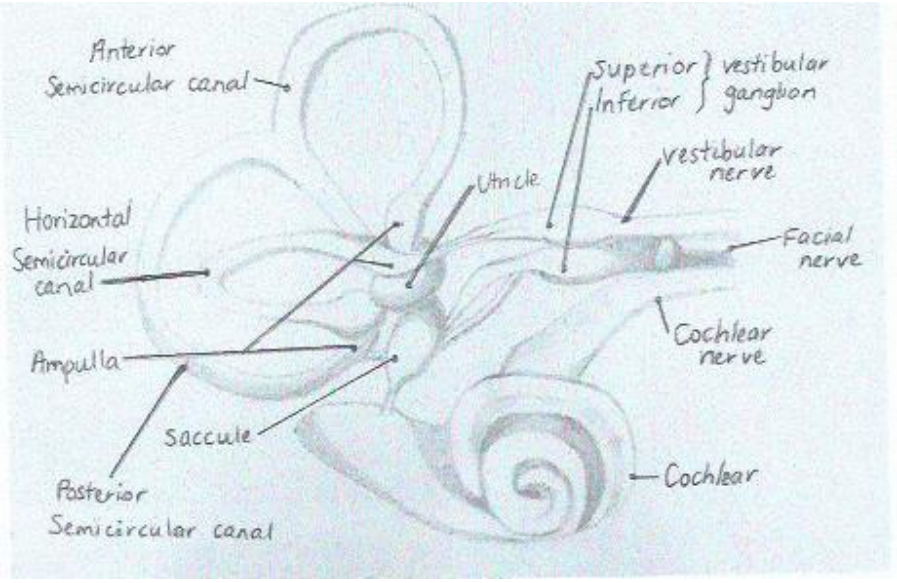


Figure 2-1 Illustration of right peripheral vestibular and auditory systems (Personal)

There are three semicircular canals on each side (horizontal, anterior and posterior), which are orientated at approximately 90-degree angles from each other [18]. Each canal is coupled functionally with a canal in the opposite inner ear [18]. Semicircular canals are filled with ducts of endolymph fluid, which moves freely within each canal in response to the direction of the angular head motion [18]. At one end of each semicircular canal there is an enlargement known as an ampulla, located near the junction of the utricle. Specialised sensors known as hair cells are located within each ampulla and within the otoliths [18]. The hair cells respond to acceleration of the head and the acceleration signal is then transformed into a velocity signal. These hair cell sensors respond to the endolymph fluid movement and to the angular velocity of head movement in different planes [19]. Hair cell movement generates action potentials and changes the firing rate in the vestibular nerve. The peripheral system is tonically active with a resting firing rate and the firing level of the vestibular nerve will increase and decrease with head movement [20, 21]. The canals respond to angular velocity and the otoliths to linear acceleration. Structural arrangement of the peripheral vestibular system is illustrated in Figure 2-1.

2.1.2 Physiology

The vestibular ocular reflex (VOR) and vestibulospinal reflex underpin the motor functions of the vestibular system [21, 22]. The VOR functions to enable gaze

stability - maintenance of stable vision when the head is moving – by controlling the eyes (via activation of the appropriate ocular muscles) to move in the opposite direction and at an equal velocity to the head [22]. Some problems of the vestibular system may cause disorder of the VOR and therefore cause problems with gaze stability [15]. The primary function of the vestibulospinal reflex is to maintain and regain postural control during movement and this is achieved through activation of vestibulospinal pathways [21]. The central nervous system integrates information gained from the peripheral vestibular system in conjunction with information received from other sensory systems, to assist with calibration of the VOR, contribute to postural control and influence co-ordination of limb movements [18].

When vestibular function is normal, these reflexes operate with superb accuracy and with short latencies to produce eye movements, gaze stability and postural control during head movement or when the head / body is rotated through space, such as when turning or twirling [18].

For clear vision whilst the head is moving, the velocity of the eyes should be exactly opposite the head movement [22]. The VOR can only maintain this level of accuracy for a short time, for high frequency movements [22]. The brainstem structure called the velocity storage mechanism perseverates the response, allowing for stable vision during low frequency head movements [23].

2.1.3 Dizziness

The term "dizziness" is either defined as an umbrella term that includes "vertigo" as a subset [24], or as a separate entity. The Committee for Classification of Vestibular Disorders of the Barany Society defined dizziness as "the sensation of disturbed or impaired spatial orientation without a false or distorted sense of motion" [16]. This definition of dizziness does not include vertiginous symptoms [16]. Vestibular disorders may cause either or both symptoms of dizziness and vertigo, however there are several non-vestibular causes of dizziness symptoms. Non-vestibular causes of dizziness symptoms include cardiac diseases [3], orthostatic hypotension, dehydration, drugs, environmental pressure shifts, exercise, hyperventilation, hormones, phobic situations, tight neck collars, and vibration [16].

2.2 Prevalence of dizziness, vertigo and vestibular disorders

Prevalence studies of interest in this thesis can be categorised into three sections: prevalence of dizziness; prevalence of vestibular vertigo / disorders; and prevalence of specific vestibular disorders. Prevalence is the proportion of a population who have a specific characteristic in a given time period [25]. High prevalence rates of dizziness, vestibular vertigo / vestibular disorders highlight the importance of screening for vestibular disorders in people who present to hospital with symptoms of dizziness / vertigo in order to provide improved intervention.

2.2.1 Prevalence of dizziness

Dizziness is one of the most common symptoms in older people presenting for medical intervention [26-29] with a reported prevalence of 30% - 45% in people over the age of 65 years [27, 29]. Prevalence of dizziness across the life span is 20%, higher in females (27%) than men (14%) [30]. Table 2-1 highlights studies of dizziness epidemiology with data reported from several countries.

Table 2-1 Prevalence of dizziness by population within a country

Prevalence of Dizziness in the population	Dizziness (%)
Dizziness, n = 2751 (Australia) [2]	36.2
Dizziness, n = 2547 (Sweden) [30]	21.0
Dizziness, n = 1287 (Germany) [31]	15.8
Dizziness or faintness, n = 17,638 (Sweden) [32]	28.7
Dizziness in people over the age of 65 years, n = 1801 (Germany) [33]	29.0
Dizziness in people over the age of 65 years, n = 2925 (United Kingdom) [34]	11.1
Dizziness or imbalance in people over age of 70 years, n = 2011 (Sweden) [28]	36.0
Dizziness in people over the age 65 years or older, n = 6158 (United States of America) [35]	9.6
Dizziness defined as imbalance in people over the age of 40 years, n = 5086 (United States of America) [36]	35.4

2.2.2 Prevalence of vestibular vertigo / vestibular disorders

The prevalence of vestibular disorders has been estimated in several studies. Forty-four percent of people with dizziness complaints were found to have a peripheral vestibular disorder, as reported in a meta-analysis of 12 articles [37]. Table 2-2 highlights the prevalence of vestibular vertigo / disorder in the general population, reported in studies using questionnaires about symptoms.

Table 2-2 Prevalence of vestibular vertigo/ disorder by population within a country

Prevalence of vestibular vertigo / disorder, n = study size	Percentage of people with vestibular vertigo
Vestibular vertigo, n = 4869 (German) [38, 39].	4.9
Vestibular vertigo, n = 2547 (Sweden) [30]	10.5
Vestibular vertigo in people over the age of 50 years, n = 2751 (Australia) [2]	10.0
Vestibular disorder in ENT clinic (Japan) (non-BPPV) [40]	22.0

Abbreviations: ENT, ear nose throat; BPPV, Benign Paroxysmal Positional Vertigo

Lifetime prevalence of vestibular vertigo / disorder is 7.4%, 1-year prevalence is 4.9%, and 1-year incidence is 1.4% [39]. Vestibular vertigo / disorder is three-times more likely in older people and almost has a 3-fold female preponderance [38, 39]. The difference between females and males is greater in vestibular vertigo / disorder compared with dizziness, reported in Section 2.2.1.

2.2.3 Prevalence of specific vestibular disorders (based on objective tests)

Benign Paroxysmal positional vertigo (BPPV) (see Section 2.5.1) is the most common vestibular disorder and has been reported to account for one-third of vertigo presentations to dizziness clinics [41, 42]. It is reported that between 17 and 42% of people presenting to a United States of America health clinic with vertigo, ultimately receive a diagnosis of BPPV [43-45]. BPPV is highly prevalent in ear nose throat clinics [46] with a lifetime prevalence of 2.4% and a one-year prevalence of 1.6%, with a 0.6% incidence of new cases. It is a common vestibular disorder across the lifespan, although age of onset is most commonly between the ages of 50 and 70 years [42]. Incidence of BPPV increases with age [46, 47], with 3.4% prevalence in people over the age of 60 years, and a 10% lifetime incidence by the age of 80 years [47]. Fifteen percent of people can experience BPPV after vestibular neuritis [48].

Vestibular migraine is reported as the second most common cause of dizziness [49] and the most common cause of episodic spontaneous vertigo attacks [50]. Vestibular migraine has a reported prevalence of 6-10% in people attending dizziness clinics and a lifetime prevalence of 0.98% and a 0.89 one-year prevalence [38, 51, 52]. For women, aged 40-54 years old, the prevalence of vestibular migraine is 19.4% [53]. Thirty percent of women aged 40-54 years with a history of migraines also have vestibular migraine [53].

Vestibular neuritis is a common cause for dizziness complaints and the prevalence varies from 11.7 to 15.5 per 100,000 per year [54]. Bilateral vestibular hypofunction has a prevalence of 28 per 100,000 [55]. The prevalence of Meniere's disease is approximately 34-190 per 100,000 [56-58].

2.2.4 Prevalence of dizziness / vertigo / vestibular disorders in the acute hospital setting

Dizziness has been reported as a common complaint of people presenting to ED, accounting for 4% of all major complaints in the ED [13]. A study completed in the United States of America in 2009, used the National Hospital Ambulatory Medical Care Survey to review ED visits between 1993-2005 [3]. From a total of 9474 dizzy cases, (3.3% of ED visits), 33% of presenting people with dizziness were due to vestibular / otologic disorder, based on objective tests [3]. Cardiovascular (21.1%), respiratory (11.5%) and neurological conditions (11.2%), were responsible for the remainder of presenting people with dizziness [3]. Four percent of the neurological conditions group were from cerebrovascular (stroke) as the cause of dizziness [3].

Vestibular disorders have also been reported as high as 45% as an underlying cause of people complaining of dizziness [4]. In ED, presentations of dizziness complaints can be attributed to a peripheral vestibular disorder in 34% of people and central vestibulopathy in 6%, based on objective tests [37]. The meta-analysis of 12 papers reporting these findings [37] included 4 studies in the ED setting however 3 out of the 4 studies did not include vestibular testing as part of the diagnosis for a

vestibular disorder. This meta-analysis highlights the limitations of available evidence for prevalence of vestibular disorders in ED. However, non-emergent vestibular disorders (non-life threatening) are more common than emergent disorders (potentially life threatening), in people who present to hospital with dizziness complaints [59].

The available literature reports on the high prevalence of vestibular disorders in the hospital setting, providing support for the importance of this research thesis. This research thesis targets this highly prevalent population group to inform best intervention strategies in the hospital environment.

2.3 Demands on ED health care services

Demands on EDs throughout Australia are increasing [60]. Time targets, defined as the proportion of patients admitted or discharged from EDs within 4 hours of presentation, have been introduced to address the increased demand on EDs and the larger health system [61]. While these time-performance strategies provide policy stimulus to address overcrowding, meeting time-targets has not been proven to be universally associated with better outcomes for patients [62]. Concerns have been raised that these time pressures can lead to inappropriate admissions and referrals, compromise clinicians' ability to care for patients, and place pressure on staff to make decisions without sufficient time to create a management plan [63]. Consequently, adverse outcomes such as missed diagnosis, inferior clinical

outcomes, re-presentations to ED, and poorer patient satisfaction may increase for patients presenting to ED, including those with dizziness / vertigo complaints.

Health care priorities for emergency medicine vary around the world. The US for example, focus on developing payment and delivery models, supporting provision of high quality, cost-efficient care [64]. Alternatively, the United Kingdom and Australasia focus on quantifying health care using time-based performance measures that address patient outcomes associated with overcrowding and long waiting times in ED [65, 66]. Given the high prevalence of dizziness, vertigo and vestibular disorders (see Section 2.2), improved quality of care for vestibular disorders is increasingly important to patients, clinicians, organisations, and policy-makers.

2.4 Consequences of vestibular disorders and dizziness

There are many consequences of vestibular disorders and dizziness, which are discussed in this section to highlight the importance of correct identification and management for people who present to hospital with vestibular disorders and / or dizziness complaints. Vestibular disorders can be debilitating and cause adverse effects on individuals and accumulatively on society.

2.4.1 Consequences on individuals with dizziness and / or vestibular disorders

A vestibular disorder and its consequences can lead to devastating experiences including loss of balance and increased incidence of falls [6, 67, 68], reduced function, activity and community participation [67, 69, 70] with studies showing an association between dizziness and falls, a potentially debilitating occurrence. Further documented consequences of vestibular disorders include depression [71] and social embarrassment, isolation, and anxiety [72, 73].

The burden of vestibular disorders appears to be substantial [7, 29, 38]. There are many social and work impacts of dizziness [7, 29, 38]. It is common for adults with dizziness to change jobs (27%), give up work (21%), report reduced efficiency (50%), report disruption in social life (57%) and have difficulties with travel (50%) [7]. Dizziness / vertigo / vestibular disorders have been associated with considerable personal and health care burden [74]. In particular, people with vestibular disorders are significantly more likely to be followed up with visits to medical practitioners and require sick leave [38, 74]. Eighty percent of people with a vestibular disorder report the need for sick leave or medical consultation [38]. Vestibular disorders cause people to have reduced physical activity, remain house bound, and have a reduced quality of life compared with people without dizziness symptoms [38, 74]. Adults with dizziness complaints, aged 65 years and over, also

have associated fatigue, depressive symptoms, recurring falls and excessive drowsiness [29].

People with dizziness and vestibular disorders have reported reduced quality of life [11, 75, 76] and increased depressive and anxiety levels [10, 11, 77]. People from neurootology clinics report high levels of anxiety and depression distress [10]. Almost 20% of people with vertigo symptoms, who present to ear nose throat clinics, also have depressive symptoms [77].

Adults with chronic dizziness have great psychological distress, which has a detrimental influence on their quality of life [11]. Specific to the vestibular disorder Meniere's disease, vertigo symptoms have a comparable impact on quality of life to chronic health problems [75]. Quality of life of people with Meniere's disease has been shown to be similar to that of people with Alzheimer's disease before institutionalise, and cancer, days before death [76]. Additionally, bilateral vestibular hypofunction (see Section 2.5.5) has considerable impact on socio-economic and quality-of-life [55].

Quality of life to people and caregivers are affected by delays in the diagnosis and treatment of BPPV [78]. BPPV is 'a common vestibular disorder leading to significant morbidity and psychosocial impact' [47]. BPPV is also more common in older individuals with a correspondingly more marked impact on health and quality of life [79].

2.4.2 Falls and impaired balance / mobility due to vestibular disorders

There appears to be a link between vestibular disorders and falls. Studies have been undertaken predominantly in community settings and out-patient clinics, with fewer studies completed in the acute hospital setting, such as ED. This section will discuss the importance of falls and its association with vestibular disorders and / or dizziness / vertigo symptoms, and the literature on falls and vestibular disorders in the ED / AME settings.

2.4.3.1 Importance of falls

There is an established association between vestibular disorders and falls, which is of concern as the impact of falls on the individual and society is great [80]. The World Health Organisation defines a fall as 'inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects [81]. Falls are the most common cause of injury in Australia [82] and are a leading cause for hospitalisation, especially in adults 65 years and older [82]. The problems of falls and fall related injury are growing, with an increasing rate of falling per year in Australia [82]. Falls are costly to the individual and the health care system through their impact on a patient's morbidity and mortality. Direct medical costs of falls in the year 2000, in the United States of America alone, was $30 billion USD [83]. Falls lead to increased hospital length of stay [84] and increased need for institutionalisation, rehabilitation, and home care

[85]. Risk of fall is increased after one fall occurs, ultimately increasing the morbidity and mortality rate in older people [86].

2.4.3.2 Fear of falling and association with falls and dizziness.

Fear of falling is defined as 'a lasting concern about falling that leads to an individual avoiding activities that he/she remains capable of performing' [87]. Fear of falling often follows a fall, but equally, fear of falling can increase risk of falls and precipitate falls, independent of fall risk factors [88]. Strong associations have been identified between fear of falling and reduced quality of life, activity restriction, loss of independence, and fall-risk; a leading cause of injury, morbidity, and mortality [89].

Fear of falling is highly prevalent in people with dizziness [90]. Over seventy percent of people with dizziness complaints, also have a fear of falling, compared to 31% in people without dizziness symptoms [90]. Fear of falling has been detected in 71.5% of an elderly population with recurrent dizziness [91] suggesting that the majority of older people with recurrent dizziness experience a fear of falling. Risk of falls and fear of falling are therefore important to consider in association with people with dizziness complaints.

2.4.3.2 Association of dizziness / vertigo / vestibular disorders and falls

Postural control and balance is important to minimise incidence of falls [92]. Postural control is a complex motor skill and requires interaction from the

vestibular, somatosensory and visual systems [93-95]. In order to maintain postural control, the vestibular, somatosensory and visual systems provide information to our brainstem and cerebellum [93-95]. This information is collated to produce motor outputs in the form of the vestibulospinal reflex and the VOR (see Section 2.1.2). These reflexes allow for adjustments to postural sway and gaze stability, during movement and function [93-95]. There is significant decline in vestibular hair cells in non-symptomatic aging adults [96, 97]. Additionally, healthy aging adults have reduced gaze stability and reduced VOR function, and semicircular canal and otolith end organ dysfunction [98]. Age-related decline in these systems [98] are argued to be the cause of why imbalance and dizziness are common problems among older people [86]. For older people to maintain postural stability, they have to compensate for impaired sensory cues from the decline in the vestibular, somatosensory and / or visual systems. Age-related disorder of the vestibular system, including loss of vestibular otolith-ocular function is associated with increased medio-lateral measures of sway and balance disturbance, which have been shown to be related to increased risk of falls [86, 99, 100]. Age has an impact on balance with older people having a higher incidence of falling when confronted with altered visual or somatosensory inputs [101].

There appears to be a relationship between falls and vestibular disorders especially in the older population [36, 102]. Vestibular disorders are more prevalent in older

adult fallers versus non-fallers [9]. Three out of four older persons assessed for falls risk, will demonstrate evidence of a vestibular disorder [36]. Fifty-three percent of older people with a chronic vestibular disorder have had a fall in the previous year and 29.2% are recurrent fallers [102]. There is also an association between unilateral vestibular hypofunction and an increased incidence of falls and fall related injuries such as wrist and hip fractures [103, 104]. People with bilateral vestibular hypofunction have a higher incidence of having a fall, and fall related injury, compared to people without bilateral hypofunction [55]. Screening for vestibular disorders does not routinely occur when a person presents to ED with dizziness complaints [4, 14, 105]. Due to the high percentage of fallers with vestibular disorders, a quick reliable and valid tool to screen for vestibular disorders in the ED / AME is needed.

There is an increased risk of falling among adults with dizziness compared to adults without dizziness [106]. Adults with dizziness have a fall rate of 34% compared to 9% in adults without dizziness [106]. Additionally, adults with dizziness who have a fall have a 50% increased likelihood of having a fall related injury [106]. Symptoms of dizziness are particularly common in the older person and older people with dizziness are at a high risk for falls [107, 108]. Forty percent of individuals over the age of 85 years report symptoms of dizziness [107]. It is particularly important to

screen older people for vestibular disorders when they present to hospital with complaints of dizziness.

Whilst there have been many studies that investigate falls and vestibular disorders in those with chronic vestibular disorders or in the out-patient and community settings, there is limited literature in the ED setting. Eighty percent of people who present to ED with an unexplained cause for falling, suffer from symptoms of vestibular disorder [99], which may be responsible for their imbalance and fall. However, in contrast to the above findings, it has been reported that people in ED / AME with acute unilateral vestibular hypofunction do not have an increased risk of falling [109]. Further research is warranted to investigate falls and vestibular disorders in the ED setting due to the lack of literature and contrasting findings in existing literature.

Overall, the associations between vestibular disorders and falls appear to be well established in settings other than ED / AME. It is important to assess for balance disturbance and mobility to determine falls and functional ability and fear of falling in people with a suspected vestibular disorder presenting to hospital. If a quick, reliable and valid vestibular screening tool were developed for use in ED / AME then assessment and treatment of vestibular disorders may follow.

2.4.3 Financial costs associated with dizziness and vestibular disorders

Dizziness and vestibular disorders are associated with substantial healthcare costs [5]. Costs associated with management of vestibular disorder are significant [5, 12], as well as costs to arrive at a diagnosis in the ED setting [5]. The total United States of America national costs for people presenting with dizziness complaints to the ED are considerable and have been reported to exceed $4 billion per year (about 4% of all ED costs) [5]. High costs appear to reflect the high prevalence of ED visits for dizziness and high rates of imaging use [5].

Diagnosis and treatment of vestibular disorders are important issues in the hospital setting [74, 105]. Consequences of vestibular disorders on individuals and the financial burden on society [5, 7, 8, 12, 29, 38] associated with assessing and managing vestibular disorders in the ED / AME have been noted for the planned research program informing this thesis. The negative consequences of vestibular disorders on the individual and the high cost associated with managing vestibular disorders in the hospital setting highlights the importance of screening people with non-emergent dizziness for a vestibular disorder in the ED / AME setting. It is postulated that when a person presents to hospital with symptoms of dizziness, they should be screened for a vestibular disorder and referred for management.

Costs to people and caregivers are affected by delays in the diagnosis and treatment of BPPV [78, 110]. Due to the high prevalence of BPPV (see Section 2.2.3), the

impact on health care and society is high. In turn, there are significant costs to the healthcare system through both direct and indirect costs of BPPV. It has been estimated to cost $2000 USD per person to diagnose and manage BPPV in the hospital setting due to inappropriate assessment and treatment [111]. The conservative objective estimations to diagnose and manage BPPV include physician visits, audiometric testing, brain imaging, and treatment expenses [111]. Healthcare costs associated with the diagnosis of BPPV alone are almost $2 billion per year in the United States of America [110]. These costs are high considering that the Hallpike-Dix test, which is used to diagnose BPPV, is inexpensive (see Section 2.6.3). Medical costs of treating BPPV from presentation to referral has been calculated as €363 per individual (mostly for non-specific medical treatments) instead of the €136 needed for effective positional treatment [112]. Inappropriate and unnecessary assessment for BPPV raises the need for a clinically effective assessment, referral and management, which could be in the form of a hospital based, physiotherapy vestibular service.

2.5 Classification of vestibular disorders

People who present to hospital with symptoms of dizziness / vertigo can be classified into groups:

- recurrent positional vertigo, is most often due to BPPV [105];

- episodic-spontaneous vertigo, commonly due to vestibular migraine or Meniere's disease [105];
- acute vestibular syndrome, typical of either vestibular neuritis or stroke [105];
- non-vestibular causes of dizziness may be from hypotension, cardiac rhythm disturbances, hypoglycemia, anemia, and anxiety [105].

The purpose of this section is to outline the pathophysiology of vestibular disorders commonly seen in the ED / AME. This is relevant as this thesis targets people who present to hospital with dizziness complaints with an interest in those with a vestibular disorder.

Additionally, unilateral and bilateral vestibular hypofunction are highlighted in this section, as vestibular disorders such as vestibular neuritis and Meniere's disease often result in vestibular hypofunction, requiring screening, assessment and treatment. Other disorders that may cause symptoms of dizziness / vertigo are briefly highlighted, concluding this section.

2.5.1 Recurrent positional vertigo: Benign paroxysmal positional vertigo

BPPV is defined as a disorder of the inner ear characterised by repeated short-lived episodes of vertigo associated with changes in head position [113]. The name benign paroxysmal positional vertigo encompasses the associated clinical features. The descriptor *benign* historically implies that BPPV prognosis for recovery is

favourable and is not due to any serious central nervous system disorder. However, the health impacts of undiagnosed and untreated BPPV may not be "benign". Older adults with BPPV have a higher incidence of falls, depression and impairments of their daily activities [114], causing personal and societal health burden. The term *paroxysmal* connotes the unexpected (and inexplicable), sudden onset and short-lived nature of vertigo associated with an episode of BPPV. *Positional* vertigo is defined as 'a spinning / rotational sensation produced by changes in head position relative to gravity' [110].

Characteristically, people with BPPV report sudden onset of brief (often less than 1 minute) episodes of vertigo provoked by changes in head position relative to gravity, for example turning over in bed, tipping the head back or bending over [110]. Symptoms of nausea, vomiting and postural imbalance are often associated with the vertigo [113].

The etiology of BPPV is thought to be due to the presence of abnormal utricular otoconia entering and becoming trapped in a semicircular canal either floating free in the canal (canalithiasis) or adhering to the cupula (cupulolithiasis) [110], see Figure 2-2. The trapped debris causes inertial changes in the endolymph, making the semicircular canals responsive to gravity, causing abnormal nystagmus and vertigo with head motion in the plane of the canal [110]. These two types of BPPV can occur in any of the semicircular canals or within multiple canals, but the

posterior canal is most commonly involved constituting approximately 85-95% of BPPV cases [110]. Horizontal canal BPPV accounts for 5-15% of BPPV cases and anterior canal is reportedly rarely involved [110]. BPPV's etiology is unknown, however, in many cases it can be preceded by vestibular neuritis or head trauma [110].

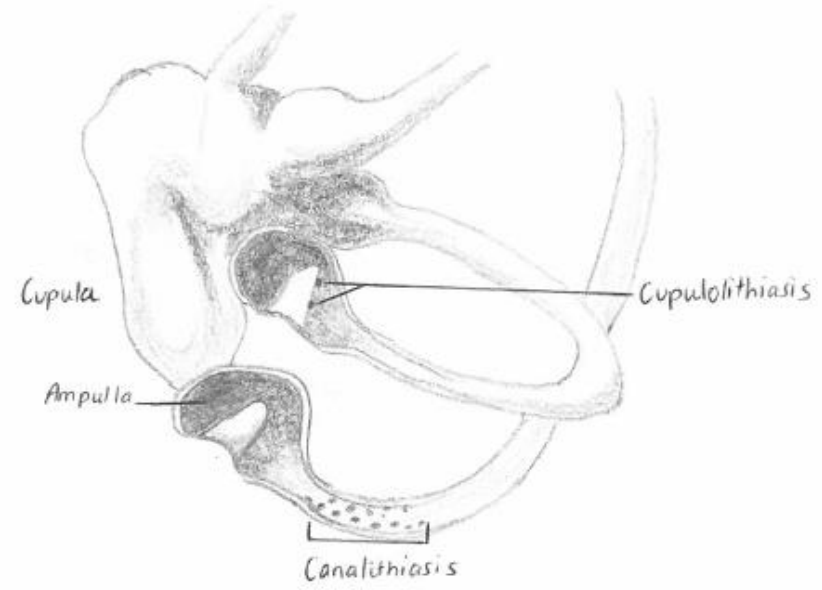


Figure 2-2 Benign paroxysmal positional vertigo canalithiasis and cupulolithiasis (Personal)

2.5.2 Episodic spontaneous vertigo

2.5.2.1 Vestibular migraine

Vestibular symptoms associated with vestibular migraine was recently unknown or believed to be largely speculative. However, in 2013, members of the International Headache Society collaborated with members of the Barany Society to publish

diagnostic criteria for vestibular migraine [115]. The guideline utilises specific criteria to identify vestibular migraine [115]. Diagnosis is based on 'symptom type, severity and duration, a history of migraine, temporal association of migraine symptoms with vertigo attacks, and exclusion of other causes' [115]. Vestibular migraine is typically an episodic disorder, with attacks ranging in length from seconds to days [115]. Vascular changes affect the peripheral vestibular system and cortical changes affect the central nervous system, in vestibular migraine [116].

Diagnostic criteria for vestibular migraine

The diagnostic inclusion criteria for vestibular migraine include [115]:

A. 'at least 5 episodes with vestibular symptoms of moderate or severe intensity, lasting 5 min to 72 hours',
B. 'current or previous history of migraine with or without aura according to the International Classification of Headache Disorders',
C. 'one or more migraine features with at least 50% of the vestibular episodes:
   – headache with at least two migraine characteristics (one sided location, pulsating quality, moderate or severe pain intensity, aggravation by routine physical activity, photophobia and phonophobia, visual aura)',
D. 'not better accounted for by another vestibular or International Classification of Headache Disorders diagnosis'.

2.5.2.2 Meniere's disease

Meniere's disease is a multifactorial disorder where the combined effects of environmental factors and genetics probably determine the onset of disease [117]. Histopathological studies found Meniere's disease to be associated with endolymphatic hydrops, the accumulation of endolymph in the cochlear duct and vestibular organs [118]. However, endolymphatic hydrops do not explain all clinical features, including progressive hearing loss and the frequency of vertigo attacks [119].

Diagnostic criteria for Meniere's disease

The diagnostic criteria for definite Meniere's disease include [117]:

A. 'two or more spontaneous episodes of vertigo, each lasting 20 minutes to 12 hours',
B. 'low- to medium frequency sensorineural hearing loss in one ear, defining the affected ear on at least one occasion before, during or after one of the episodes of vertigo (tested via audiometry)',
C. 'fluctuating aural symptoms (hearing, tinnitus or fullness) in the affected ear',
D. 'not better accounted for by another vestibular disorder'.

2.5.3 Acute vestibular syndrome

Acute vestibular syndrome is characterised by rapid, acute onset of vertigo, intolerance to head motion, gait instability, spontaneous or gaze evoked nystagmus,

nausea and / or vomiting, and a duration of at least 24 hours to several weeks [120-124]. Acute vestibular syndrome may be caused by: [105]

- non-emergent vestibular disorder, caused by vestibular neuritis,
- emergent disorder, caused by posterior circulation stroke.

Non-emergent vestibular disorders are more common than emergent disorders, as a cause for acute vestibular syndrome [105, 125]. The most common non-emergent cause of acute vestibular syndrome is of a peripheral vestibular origin, vestibular neuritis or the rare labyrinthitis [125, 126]. The most frequent emergent cause of acute vestibular syndrome is from a central origin, posterior circulation stroke, most commonly in the cerebellum or lateral brainstem [125]. Other less common causes of acute vestibular syndrome include multiple sclerosis, cerebellar haemorrhage, labyrinthine haemorrhage, Meniere's disease, vestibular migraine, autoimmune, infectious or metabolic conditions [126-130].

Clinical differentiation of acute vestibular syndrome in the ED / AME (i.e. whether it is from a peripheral or central origin) is of prime importance in order to commence effective therapeutic and secondary prophylactic treatment [126]. Whilst the focus of this thesis is on non-emergent vestibular disorders, it is important to understand the clinical differentiation process between emergent and non-emergent conditions as this thesis centres around the acute hospital setting.

2.5.3.1 Vestibular neuritis

Vestibular neuritis is thought to be caused by a virus (herpes simplex virus) resulting in selected labyrinthine damage [131]. A partial loss of vestibular function, usually the superior portion of the vestibular nerve, is more common than a complete loss involving the superior and inferior portion of the vestibular nerve [132], due to unknown reasons [131]. Symptoms of vestibular neuritis include an acute onset of vertigo, usually with associated nausea and vomiting, gait imbalance, head motion intolerance and spontaneous nystagmus fixed in direction [133]. Whilst hearing is preserved with neuritis, labyrinthitis, which is rare, results in unilateral hearing loss [134]. The acute symptoms of vestibular neuritis improve over one to four days [132]. Vestibular neuritis results in a unilateral vestibular hypofunction [133] (see Section 2.5.4).

2.5.3.2 Posterior circulation stroke

Posterior circulations stroke accounts for 10-20% of all ischaemic strokes [135] and is challenging to recognise as it often occurs without neurological signs such as hemiplegia, visual agnosia, amnesia and neglect [135]. The posterior inferior cerebellar artery is most commonly involved (approximately 96%) followed by the anterior inferior cerebellar artery (approximately 4%) [136]. Additional to cerebellar infarctions, brainstem infarctions may also cause acute vestibular syndrome [120]. Early identification of a posterior circulation stroke in the acute

hospital setting is important to provide early reperfusion strategies, which have been shown to be safe and beneficial [135].

2.5.4 Unilateral vestibular hypofunction

A common cause for unilateral vestibular hypofunction is vestibular neuritis (see Section 2.5.3.1) or the uncommon labyrinthitis [132]. Other causes of unilateral vestibular hypofunction include Meniere's disease (see Section 2.5.2.2), ablation surgery of vestibular nerve, or vestibular schwannoma [137].

The patient with unilateral vestibular hypofunction usually has three main problems [137]:

- decreased gain of the VOR, leading to decreased gaze stability during head movement;
- vertigo or dizziness or associated symptoms at rest or during head movement (head motion sensitivity);
- disorder of balance and gait.

2.5.5 Bilateral vestibular hypofunction

Bilateral vestibular hypofunction is less common than unilateral vestibular hypofunction and is typically caused by vestibulotoxic medications such as gentamycin [138]; systemic pathology such as autoimmune disease, which often does not result in dizziness or vertigo due to the lack of imbalance between the two

vestibular systems; and, sequential unilateral vestibular hypofunction resulting in a bilateral loss [139].

The onset of bilateral vestibular hypofunction may be sudden or progressive. Symptoms are commonly postural instability and oscillopsia (gaze instability) [140] however in the case of sequential unilateral vestibular hypofunction, vertigo will be experienced prior to the onset of postural imbalance and oscillopsia [140].

2.5.6 Other disorders causing dizziness / vertigo symptoms

A range of other disorders causing dizziness are beyond the scope of this thesis as they are less common including vestibular labyrinthitis, cervicogenic dizziness, perilymphatic fistula / superior canal dehiscence, vestibular schwannoma, Ramsay hunt syndrome, concussion, multiple sclerosis, visual vertigo, autoimmune inner ear disorder, mal de debarquement, vestibular paroxysmia, vestibular atelectasis, and non-vestibular dizziness (medications, central degenerative disorders, systematic metabolic disease, orthostatic hypotension, anxiety).

After planning for this research thesis, a new diagnosis 'persistent postural-perceptual dizziness' was made for a set of clinical characteristics related to dizziness [141]. This diagnosis was also not included as part of these studies as it was only more recently published.

2.5.6.1 Other causes for symptoms of dizziness / vertigo from a central origin

Pathological changes to the central nervous system causing vestibular disorder are most commonly caused by vestibular migraine and strokes affecting the cerebellum and brainstem. However, central disorders caused by vascular (stroke), degenerative conditions or tumours, can give rise to symptoms of dizziness, vertigo and imbalance [105]. In particular dorsal lateral medullary infarct causes vertigo symptoms [105]. Less frequent pathologies include Parkinson's disease [142], multiple sclerosis [129], cerebellar paraneoplastic syndrome, genetic disorders [143], and a newly identified subtype of bilateral vestibular hypofunction, termed Cerebellar Ataxia, Neuropathy, and Vestibular Areflexia Syndrome (CANVAS) [144]. This syndrome includes bilateral positive head impulse test, amongst central features such as direction changing gaze evoked nystagmus and abnormal VOR at slow speeds and shows no recovery in the long term to treatment [145].

2.6 Assessment of vestibular disorders

This section details physiotherapy vestibular assessment, laboratory tests used for vestibular disorder diagnosis, and assessment for recurrent positional vertigo, episodic spontaneous vertigo and acute vestibular syndrome. The differential diagnosis for acute vestibular syndrome is explained, differentiating between the emergent diagnosis of posterior circulation stroke from vestibular neuritis [146]. It is important to discuss the clinical differentiation for acute vestibular syndrome,

excluding emergent conditions of posterior circulation stroke, despite the focus of this thesis on non-emergent vestibular disorders that present to hospital. The section concludes with details of screening of non-emergent vestibular disorders in the acute hospital setting.

2.6.1 Physiotherapy vestibular assessment

A vestibular assessment assists in the diagnosis of a vestibular disorder [125, 147]. The assessment includes a comprehensive history and objective assessment [105, 137, 148].

2.6.1.1 The history

The interpretive history from the person with vestibular disorder guides the clinical reasoning process towards a diagnosis of vestibular disorder [105].

Symptoms

Symptoms can assist in the differential diagnosis of people complaining of dizziness. Common symptoms of vestibular disorders include vertigo, imbalance, nausea and vomiting. Asymmetrical input from the peripheral vestibular system and / or asymmetric integration of vestibular input into the central nervous system is thought to form the basis of vertigo [18]. Symptoms of nausea, vomiting and anxiety associated with vestibular disorders are thought to be a result of abnormal activation of the autonomic and reticular pathways in the central nervous system as this system interprets any asymmetry in the firing rate of the vestibular nerve as

movement [10, 18]. Whilst vertigo is associated with vestibular disorders, the patient reported quality of dizziness, for example if it is vertigo or dizziness or light-headedness, is unreliable to determine if symptoms are from a vestibular origin or not [24]. Throughout the studies of this thesis, when someone used different terms instead of 'dizziness', such as light-headed, swimming, woozy, off-balance, further clarification of the symptoms was sought via additional subjective questioning.

First attack or recurrent vertigo

Establishing if this is a first attack or recurrent vertigo helps direct diagnosis and required objective assessment. A first attack of vertigo (lasting longer than 24 hours) is from an acute vestibular syndrome likely from vestibular neuritis or stroke, whereas episodic vertigo could be BPPV, vestibular migraine, Meniere's disease, amongst other less common vestibular causes.

Spontaneous or positional

When symptoms appear spontaneously, the underlying cause may be a virus resulting in vestibular neuritis, Meniere's disease or a posterior circulation stroke [105]. When symptoms are provoked by change in head position, it may be from BPPV, vestibular migraine or a non-vestibular disorder such as orthostatic hypotension. What position or change in position triggers the dizziness can help distinguish among these disorders. For example, lying down, rolling over and looking up are more likely to provoke vertigo associated with BPPV [110]. Standing

up quickly is more likely to provoke dizziness associated with orthostatic hypotension [105]. Vestibular migraine may present with spontaneous vertigo or with vertigo induced by change in head position. [105]

Duration

Vertigo lasting seconds is more likely associated with BPPV whereas vertigo lasting minutes for each episode could be from posterior circulation infarction or vestibular migraine or cupulolithiasis form of BPPV. When symptoms last for hours, vestibular migraine or Meniere's disease may be responsible whereas when symptoms persist for greater than 24 hours, posterior circulation stroke, vestibular neuritis or vestibular migraine should be considered [105].

Associated symptoms

Acute unilateral tinnitus (ringing in the ears) or hearing loss in the setting of acute vestibular syndrome indicates a stroke may be the cause arising from infarction of the anterior inferior cerebellar artery [149], or that Meniere's disease is present [117]. When vertigo presents with associated neurological symptoms such as weakness, sensory loss, hiccups, dysphonia, diplopia, a cause from a central origin should be considered [105]. Migraine history and / or migraine features (see Section 2.5.2.1) make vestibular migraine more likely [150].

2.6.1.2 Objective assessment

The objective assessment helps identify the nature of the peripheral vestibular disorder and to identify any central vestibular components [125]. The objective vestibular diagnostic tests are detailed in this section and include observation for nystagmus, oculomotor examination, head impulse test, head shaking nystagmus, dynamic visual acuity, positional tests and vestibulospinal reflexes.

Observation for nystagmus

Nystagmus refers to the oscillation of the eyes with a slow phase (movement) in one direction and a fast corrective movement in the opposite direction [151]. Various types of nystagmus can be verified based on the existence of fast and slow phases (jerk nystagmus) or alternating slow phases (pendular nystagmus). There are many forms of nystagmus such as nystagmus of the blind and periodic nystagmus that are not discussed in this section.

In assessing nystagmus, a structured approach is important, as the differential diagnosis of nystagmus is broad. Pathologic nystagmus includes spontaneous nystagmus, positional nystagmus, head shaking nystagmus. Other pathologic nystagmus types that are not discussed in this section include vibration-induced nystagmus and asymmetric caloric nystagmus. Pathological nystagmus is often present with vestibular disorders [151] however of primary importance is to

differentiate between vestibular nystagmus and central nystagmus by observing spontaneous nystagmus.

Spontaneous nystagmus

Sudden loss of vestibular function unilaterally or sudden excitation of the vestibular system on one side causes an asymmetry of the tonic firing rate of the vestibular system and results in spontaneous nystagmus [152, 153]. Spontaneous nystagmus at rest is abnormal and may be associated with either a central nervous system lesion or a peripheral vestibular disorder [154]. Therefore, the direction of the nystagmus (spontaneous and gaze-evoked) is observed to assist the clinician in differentiating between a central cause of dizziness complaints and a peripheral vestibular cause, as well as differentiating between specific vestibular disorders [123].

Findings of direction-changing, gaze-evoked nystagmus, or pure torsional or pure vertical nystagmus are types of central nystagmus, indicating central pathology. Down-beating nystagmus can be an indicator of a lesion of the cerebellar flocculus or floor of the 4th ventricle while pure up-beating nystagmus is an indicator of brachium conjunction or dorsal upper medulla lesion. Pure torsional nystagmus however, is an indicator of dorsolateral medulla lesion and periodic alternating nystagmus is an indicator of lesions in the cerebellar nodulous [143].

The pattern of spontaneous nystagmus indicative of peripheral vestibular nystagmus is direction-fixed, mixed nystagmus. For example, the pattern of nystagmus of fast phase beating away from the side of the lesion and towards the more intact (active) side is evident in a unilateral peripheral vestibular hypofunction [152, 153]. Nystagmus in unilateral vestibular loss is horizontal and torsional nystagmus.

The use of visual suppression in the assessment of spontaneous nystagmus assists in differentiating between peripheral and central origin [105]. Nystagmus from a peripheral origin can be decreased with visual fixation (removal of visual suppression) however nystagmus from brainstem and cerebellar lesions (central origin) cannot. Useful methods of observing nystagmus with visual suppression / fixation blocked are opthalmoscope, ganzfield, video frenzel camera or Frenzel lenses. Video Frenzel camera / equipment (see below for details) was used in this thesis.

Positional nystagmus

Positional nystagmus most commonly is the result of BPPV, however central disorders may result in positional nystagmus. The duration of the nystagmus and the pattern of the nystagmus (direction-fixed or direction-changing) assist in determining if positional nystagmus is from a central or peripheral cause. BPPV is the most common peripheral cause for positional nystagmus. Indeed, when BPPV is

present, the direction of the nystagmus informs the involved semicircular canal, assisting with diagnosis and treatment direction [155]. For example, BPPV involving the posterior canal and the anterior canal produces vertical and torsional nystagmus. It is also noteworthy that rates of asymptomatic positional nystagmus in healthy controls is as high as 90% [156] therefore symptoms associated with positional testing when observing positional nystagmus is important.

Head shaking nystagmus

The head shaking nystagmus test is another helpful test to assist in the diagnosis of asymmetry in peripheral vestibular input and asymmetry in central vestibular regions [157]. Vision must be occluded as fixation on a visual target can suppress nystagmus [158], therefore video Frenzel equipment is used to prevent fixation. With the head flexed 30 degrees, the head is oscillated 20 times at 2Hz. A person with unilateral peripheral vestibular loss will manifest a horizontal head shaking nystagmus, with the fast phase of the nystagmus towards the healthy ear, away from the side of the lesion [159]. People with bilateral vestibular hypofunction typically do not have a head shaking nystagmus unless there is asymmetry in vestibular function between sides [159]. Nystagmus produced during this procedure indicates a vestibular hypofunction however this does not differentiate between peripheral or central origin [159].

Forty-five percent of people with a posterior anterior inferior infarction stroke were found to have head-shaking nystagmus [157]. Head-shaking nystagmus helps differentiate between peripheral and central disorders by observing the type of nystagmus [157]. Perverted head-shaking nystagmus refers to nystagmus that is induced in the plane other than that being stimulated during head shaking (cross-coupled response) [160]. It is most commonly downbeating nystagmus after horizontal head-shaking, either in the presence or absence of horizontal nystagmus as well [160]. This cross-coupled nystagmus response after the head-shaking test is indicative of central pathology [161]. Vertical head-shaking nystagmus is less informative than horizontal head-shaking and is mainly helpful when horizontal or torsional nystagmus is elicited with a vertical plane head-shaking test (cross-coupling), indicating central pathology [162].

Head-shaking nystagmus has been extensively researched to test the association with outcomes of caloric irrigation tests in people with a variety of peripheral vestibular disorders causing unilateral vestibular loss, such as vestibular neuritis, acoustic neuroma and Meniere's disease. The sensitivity of the head shaking nystagmus test for unilateral vestibular hypofunction, is shown to be 31% whereas specificity is 96% and positive predictive value is 97%, compared to caloric testing [163]. Sensitivity and specificity of this test varies with the degree of unilateral vestibular loss and with the type of vestibular disorder [157]. When the HIT and

head shaking nystagmus results are both abnormal, there is a high likelihood (positive predictive value of 80%) of a significant caloric deficit (asymmetry of ≥ 30%) (see Section 2.6.2) [164]. The two tests utilise different mechanisms to assess vestibular hypofunction and are complementary in nature [165]. Therefore, both the HIT and head shaking nystagmus test were included in this research thesis.

Video Frenzel equipment

Assessment of a person with acute dizziness requires a means of removing visual fixation otherwise spontaneous nystagmus is often missed [105]. Video Frenzel equipment allows for occlusion of vision, necessary for observation of spontaneous and gaze-holding nystagmus and head shaking nystagmus [166]. The equipment has a monocular camera that creates real-time videos and recordings of eye movements during testing [167]. Video Frenzel equipment was utilised for this thesis for observation of nystagmus (spontaneous, gaze-evoked, head shaking nystagmus) and for positional testing.

Oculomotor examination

The oculomotor examination includes ocular range of motion and alignment, smooth pursuit, saccadic eye movements, vergence, optokinetic eye movements, test of skew, and VOR cancellation [160, 168].

Normal smooth pursuit movements are slow tracking movements of the eye, intended to keep a moving object in focus. To test smooth pursuit, the person is

asked to follow an object with their eyes only, moving no faster than twenty degrees per second in the horizontal and vertical directions [105]. Age, level of consciousness and neurodegenerative disorders can impair smooth pursuit [105]. Saccades are also normal eye movements. Saccades are rapid eye movements that quickly change the point of fixation. For example, normal saccadic eye movements occur whilst reading and whilst looking around a room. To test saccadic eye movements, the person is asked to rapidly fixate on two stationary objects 50 cm apart whilst the examiner observes for saccadic latency, velocity, accuracy and conjugacy [105]. Saccadic eye movements should be normal in peripheral vestibular disorders.

Central signs can be detected in the oculomotor examination. The oculomotor examination findings of abnormal smooth pursuit, saccadic eye movements, vergence, optokinetic eye movements, VOR cancellation, and positive test of skew are indicative of a central cause to symptoms [123, 143]. Ocular hypermetria / overshooting on saccadic testing is related to cerebellar disorder, and intra nuclear opthalmoplegia on gaze testing is a sign of a multiple sclerosis lesion of the medial longitudinal fasciculus [169]. Skew deviation is observed using the alternate eye cover test where the person's eyes are alternatively covered and uncovered [123]. A vertical realignment of the eye as it is uncovered indicates a positive skew deviation, which is a sign symptoms are from a central origin [123]. Central signs usually

warrant a referral to a neurologist and magnetic resonance imaging of the brain [105].

Head impulse test

The head impulse test (HIT) assesses the dynamic component of the vestibular system. The HIT is accepted as a clinical test of the angular VOR and indicates if unilateral or bilateral vestibular hypofunction is present [167, 170, 171]. Vestibular hypofunction of the horizontal semicircular canals can be identified by the HIT, due to the asymmetric vestibular responses [170]. The head is flexed 30 degrees and the person is asked to fixate their eyes on a stationary target while their head is manually rotated in an unpredictable direction using a small amplitude (about the midline), high acceleration, horizontal thrust to the left and right. An abnormal response is when the eyes do not stay fixed on the target and a corrective saccade is made to bring the target back on the fovea, known as a refixation saccade [171]. An abnormal result in the form of a refixation saccade indicates decreased VOR and vestibular hypofunction [171]. Similarly, vertical HIT's assess the anterior and posterior semicircular canals by performing the appropriate head rotation in the planes of these canals and observing overt saccades for each canal [172].

The horizontal HIT has 100% sensitivity and 100% specificity in determining the presence of a complete unilateral vestibular nerve section [170]. The test is less sensitive in detecting vestibular hypofunction in people with incomplete loss of

function, compared to those with complete loss [170]. The HIT has been shown to have a sensitivity of 71% for unilateral vestibular hypofunction and 84% for bilateral vestibular hypofunction and high specificity (82%) compared to caloric examination, a laboratory test of vestibular ocular reflex function [167]. The HIT's sensitivity is improved when the head is pitched 30 degrees down and when the thrust is of unpredictable timing and direction [167]. For people with unilateral or bilateral vestibular hypofunction, the positive predictive value for the HIT is 87% and the negative predictive value is 65% [173].

Clinical dynamic visual acuity

People with unilateral or bilateral vestibular hypofunction often have impairment in their visual acuity during head movement [174]. The clinical dynamic visual acuity (DVA) is a test that measures difficulties with visual acuity during head movement [175]. The test compares visual acuity when the head is stationary (static visual acuity) to visual acuity when the head is moving (DVA). To complete the test, the person is asked to read each line down to the smallest possible line that can be read on the Snellen chart while the examiner manually oscillates the person's head horizontally at 2Hz [175]. Head velocities need to be greater than 100 degrees per second to ensure the person uses the VOR and not smooth pursuit eye movements to maintain visual acuity. In a normal VOR test, the person's eyes will smoothly move in the opposite direction of the head and stay focused on the target, allowing

constant ocular fixation [176]. A normal result is for the person to read the same line with their head still or the line above, with larger letters. When vestibular hypofunction is present, the VOR will not maintain stability of the eyes during head movements causing decreased visual acuity during head motion compared with a stationary head. An abnormal result is three or more lines difference between static and dynamic head movements, suggestive of possible vestibular dysfunction [177].

The frequency of head motion has an impact on clinical DVA scores in people with complete unilateral vestibular loss with scores increasing with greater frequency of head rotations [178]. The clinical DVA had weak correlations (horizontal direction: $r = 0.31$, $p = 0.38$; vertical direction: $r = 0.05$, $p = 0.91$) with the degree of vestibular deficit as measured by the caloric irrigation test in people with vestibular hypofunction [175]. Test-retest reliability is excellent ($r = 0.94$) in young adults and children [179]. Positive and negative predictive values for clinical horizontal DVA in adults with vestibular disorders has not been reported in the literature.

The DVA identifies the functional significance of dyscontrol of the VOR when vestibular hypofunction is present [180, 181]. It should improve with central compensation for a vestibular deficit and with gaze stability exercises [182]. The DVA may be useful to monitor vestibular function in people with a hypofunction during their recovery [183] and so was used in this thesis to indicate impaired gaze

stability and to demonstrate compensation of vestibular hypofunction after treatment [178].

Positional tests

Positional testing is commonly used to detect displacement of otoconia in the semicircular canals causing BPPV [110]. Guidelines suggest that people should be assessed with both the Hallpike-Dix (HPD) test and head roll tests to diagnose BPPV [110]. A positive positional test provokes vertigo and nystagmus whilst in the testing position [110]. The resultant type of nystagmus indicates which semicircular canal is affected, and the duration of the nystagmus indicates if the BPPV is canalithiasis, where the particles are free floating in the canal, or cupulolithiasis, where the particles are adhered onto the cupula [110].

The HPD [184] is the gold standard test for diagnosis of posterior (and the less common anterior) semicircular canal BPPV and has an estimated sensitivity of 79% and specificity of 75%, positive predictive validity of 96% and negative predictive value of 33% [185]. The test is well described in the literature and involves the person sitting on the bed with the legs out straight and the head rotated 45 degrees and extended 20 degrees. The person is then bought quickly onto their back with their head remaining in this position but hanging over the bed edge or over a pillow positioned under the upper back. Nystagmus is observed and symptoms are noted.

The test is repeated with the head rotated 45 degrees in the opposite direction [110].

When the HPD is unable to be performed, the alternative is the sidelying test [185]. The sidelying test has demonstrated concurrent validity with the HPD test for identifying posterior and anterior semicircular canal BPPV [185]. The estimated sensitivity of the sidelying test was 90%, specificity was 75%, positive predictive value was 96.3% and negative predictive value was 50%[185].

The head roll test is used to diagnose horizontal semicircular canal BPPV [186]. To perform the head roll test, the person is supine and their head is flexed 30 degrees and quickly rotated 45 degrees to one side and then repeated to the opposite side [110]. For horizontal BPPV, nystagmus and vertigo will occur for rolls in both directions, but slow phase velocity and duration of nystagmus will be higher when the patient is rolled towards the affected ear for canalithiasis [187] and away from the affected ear for cupulolithiasis [188]. Sensitivity, specificity, positive and negative predictive values are not available for the head roll test. The bow and lean test assists in determining the affected side for horizontal canal canalithiasis and cupulolithiasis BPPV [189]. Positional tests were used as part of the methodology for this thesis.

Vestibulospinal reflexes

Proprioception, vision and vestibulospinal reflexes all contribute to maintenance of upright posture. An acute cerebellar disorder (such as posterior circulation stroke) should be considered if static balance, that is standing with eyes open, is challenging [105]. Leaning / falling to one side in acute vestibular neuritis is common, typically falling towards the side of the problem [105]. Standing on foam with eyes closed removes the ability to use the proprioceptive and vision systems and therefore the vestibule-spinal reflexes are relied on to maintain balance [93-95]. Gait is assessed including tandem walking, observing for wide-based gait. In the setting of an acute vestibular syndrome, when wide based gait on assessment is observed, a cerebellar disorder should be considered [105] before less emergent conditions such as unilateral or bilateral vestibular loss.

2.6.2 Laboratory tests for vestibular disorders

Laboratory tests provide information about the auditory nerve and could be used to augment the clinical findings [105]. Laboratory tests include caloric irrigation tests, video HIT, rotatory chair, electronystagmyography, videonystagmyography and vestibular-evoked myogenic potential test.

The relatively new test, the video HIT, is more sensitive and specific than the clinical bedside HIT for examining unilateral vestibular hypofunction [190, 191]. The video HIT and search coil recordings were highly comparable (average concordance

correlation coefficient rc = 0.930) when tested with people with a wide range of peripheral vestibular deficits [190]. Both the sensitivity and specificity of the video HIT and the reference (search coil recordings) were 1.0 (95% confidence interval 0.69 - 1.00) [190]. Positive and negative predictive values have not been reported for the video HIT. The presence of saccades during a HIT indicates that the vestibular system is working too slowly towards the side of the impulse. The video HIT detects the presence of corrective eye saccades during (covert) and after (overt) a rapid head movement [190]. The quantitative video HIT calculates the gain between eye and head velocities. However, when compared to the caloric testing, the video HIT lacks sensitivity, in particular for moderate vestibular lesions [192].

The laboratory caloric irrigation test has previously been referred to as the gold standard for identifying peripheral unilateral vestibular hypofunction [193]. Caloric irrigation tests show an ipsilateral deficit of the VOR in unilateral vestibular hypofunction or vestibular neuritis [173, 193]. However, the caloric test is not routinely available to all people / clinicians, is performed by an audiologist with specialist training, requires expensive machinery, takes a long time to complete (often taking over an hour) and is costly. Therefore, the caloric irrigation test is not appropriate for use in the ED / AME. The video HIT, caloric irrigation tests and other laboratory tests were unavailable for use with all participants in a timely

manner. Therefore, the HIT was selected for routine use as part of the objective assessment for this thesis.

2.6.3 Assessment of recurrent positional vertigo: Benign paroxysmal positional vertigo

BPPV guidelines suggest that people should be assessed with the HPD test [78, 184] and head roll tests [110] (see Section 2.6.1.2). People with isolated BPPV will not be diagnosed unless the definitive test for posterior semicircular canal BPPV – the HPD test – is used [14]. However, the assessment for BPPV is not routinely completed in ED / AME [194].

2.6.3.1 Delay and lack of assessment for BPPV in the acute hospital setting

Recent research indicates that there is frequently a delay in diagnosing and treating BPPV, reportedly in the order of months [195]. Trained health professionals can use the HPD to accurately make a diagnosis of BPPV, however, people with dizziness are often and instead, referred for costly diagnostic tests – a frequent occurrence in the acute hospital setting [14].

BPPV is not routinely assessed for in ED [194] potentially leading to under diagnosis and treatment [4, 14, 194, 196]. It has been documented that 89% of medical providers do not evaluate for BPPV, when people present to hospital with dizziness [4]. Even when a diagnosis of BPPV is given in ED, the HPD was documented in only 21.8% of cases diagnosed [194]. This lack of diagnostic assessment is likely to be

contributing to under diagnosis and treatment [14]. An increase in the use of positional tests would improve diagnostic yield and decrease costs in evaluating people with BPPV in ED, by avoiding unwarranted and costly imaging [14]. However, anecdotally and as indicated in the literature, the HPD is not commonly used in the ED [194].

Screening of patients with a suspected non-emergent vestibular disorder, such as BPPV, is required to allow referral to have appropriate assessment and management. It is proposed that referral to clinicians that are trained to complete a vestibular assessment and can provide treatment, would be beneficial. Appropriate screening and referral may increase the use of positional tests for diagnosis of BPPV, improve diagnostic accuracy and decrease costs associated with evaluating people with BPPV.

2.6.4 Assessment of episodic spontaneous vertigo

2.6.4.1 Vestibular migraine

When assessing people with dizziness and / or vertigo, it is important to question about the presence of headaches, photophobia auras and triggers of symptoms to diagnose vestibular migraine [115], see diagnostic criteria (Section 2.5.2.1). Central spontaneous or positional nystagmus may be present during an acute attack [197]. Objective vestibular assessment and imaging are used to exclude other causes of

headaches, for example tumours or haemorrhage [50]. There are no physical tests for migraine. Diagnosis of vestibular migraine can be a challenge [198].

2.6.4.2 Meniere's disease

The diagnostic criteria for definite Meniere's disease include [117]:

A. 'two or more spontaneous episodes of vertigo, each lasting 20 minutes to 12 hours',
B. 'low- to medium frequency sensorineural hearing loss in one ear, defining the affected ear on at least one occasion before, during or after one of the episodes of vertigo (tested via audiometry)',
C. 'fluctuating aural symptoms (hearing, tinnitus or fullness) in the affected ear',
D. 'not better accounted for by another vestibular disorder'.

In ED / AME, a diagnosis of Meniere's disease is rarely made due to the diagnostic criteria [105]. This gives rise to the need to follow-up of these patients in a vestibular service. Resultant symptoms between acute attacks may be from a unilateral vestibular hypofunction [132] (see Section 2.5.4) and therefore screening and assessment is required for people who present with features consistent with a vestibular disorder to determine the need for treatment.

2.6.5 Assessment of acute vestibular syndrome - differentiating vestibular neuritis and posterior circulation stroke in acute hospital setting

Posterior circulation strokes involving the brainstem or cerebellum are emergent conditions in the acute hospital setting and may present as acute vestibular syndrome, mimicking acute vestibular neuritis. Bedside neurological examination, including the Head-Impulse-Nystagmus-Test-of-Skew (HINTS) test, is often helpful in differentiating whether the acute vestibular syndrome is of peripheral vestibular origin (non-emergent) or central origin (emergent) [126].

2.6.5.1 Head-Impulse-Nystagmus-Test-of-Skew

HINTS is a three step bedside examination that assists in recognizing stroke when dizziness presents as part of an acute vestibular syndrome [123]. HINTS test includes an assessment of the type of nystagmus (i.e. unidirectional or gaze evoked direction changing), head impulse test, and assessment of skew deviation with alternate eye cover testing [123]. A 'rule-out' process where an absence of direction changing gaze evoked nystagmus, a positive HIT and an absence of skew deviation, excludes central pathology, ie. a normal HINTS indicating a non-emergent cause to symptoms, likely vestibular neuritis [123]. The test of skew predicts brainstem involvement in acute vestibular syndrome and can help to identify stroke in people when an abnormal horizontal HIT incorrectly indicates a peripheral lesion [123].

The HINTS test appears more sensitive for diagnosing stroke than early magnetic resonance imaging in acute vestibular syndrome [123]. It HINTS has been shown to

have 100% sensitivity, 96% specificity, and 100% negative predictive value to rule out vertebrobasilar stroke in people with acute vestibular syndrome [123]. However, the study may have misclassified people into the peripheral group instead of the central (stroke) group, due to unconfirmed diagnosis of people in the peripheral group (24%). As a result, the sensitivity for ruling out stroke in patients with a negative HINTS test could be considerably lower than reported. HINTS was utilised as part of this thesis with participants that presented with acute vestibular syndrome to assist differential diagnosis of peripheral from central cause of dizziness.

The newly defined HINTS 'plus' examination, assesses for new acute onset of hearing loss [121]. A normal HINTS 'plus' examination, includes absence of newly occurring hearing loss [121, 123]. A positive HINTS 'plus' indicates a vestibular disorder of central origin [121, 123]. The sensitivity for detecting central pathology in people with AVS has been reported as 99%, specificity of 83%, and a negative predictive value of 99%. However, MRI was completed within 72 hours from symptom onset and MRI – diffusion weighted imaging has limited sensitivity for early detection of vertebrobasilar stroke [120], resulting in false high sensitivity of the HINTS plus test. Disorders that are emergent central disorders are beyond the scope of this thesis.

Medical imaging

A computed tomography of the brain is commonly ordered in the ED to assist the diagnosis of acute vestibular syndrome, however a computed tomography scan has inadequate sensitivity (< 16%) in detecting early posterior circulation stroke, despite high specificity (98%) [199-203]. Magnetic resonance imaging of the brain is more reliable in detecting stroke in acute vestibular syndrome with a sensitivity of 90% and a specificity of 97% [204].

2.6.5.2 Assessment of vestibular neuritis

In the acute stages of vestibular neuritis, vertigo is often accompanied with nausea, vomiting, postural instability and head motion sensitivity [132]. The objective signs include:

- spontaneous, horizontal torsional nystagmus that is unidirectional and increases with gaze towards the fast phase (due to Alexander's Law [205]. The nystagmus beats away from the affected side and suppresses with visual fixation [105, 166]. To ensure spontaneous nystagmus is not missed, visual fixation must be avoided with use of visual suppression [105]. Video-oculography was utilised in this thesis to achieve removal of visual fixation [206].
- positive HIT toward the affected side, with a rapid corrective saccade [105]. Vestibular neuritis affecting the superior portion of the vestibular nerve will

have a positive HIT. Vestibular neuritis only affecting the inferior portion of the vestibular nerve, which is rare, will have a negative HIT, which may mimic an emergent acute vestibular syndrome such as a posterior circulation stroke [135]. Therefore, HINTS is required to assist differential diagnosis.

- postural imbalance with an objective postural tilt toward the affected ear [137].
- normal hearing [121, 123].
- normal (rarely positive) alternate eye cover test, negative for skew deviation [105].

2.6.6 Screening for non-emergent vestibular disorders in acute hospital setting

Since the commencement and development of this thesis, diagnostic algorithms for use by ED / AME staff to differentiate between emergent and non-emergent vestibular disorders have been reported [59, 126, 127]. The algorithms foci are to identify emergent conditions in people presenting with acute vestibular syndrome, to commence treatment immediately [59, 126]. There appears to be a thought amongst clinicians in the ED setting that once an emergent central disorder is eliminated in people presenting with vertigo, discharge is appropriate, often without screening or providing intervention for non-emergent vestibular disorders.

Screening for non-emergent vestibular disorders does not routinely occur when a person presents to ED with dizziness / vertigo complaints [4, 14, 105]. It is important to identify people presenting to hospital with vestibular problems, as VPT, at least in community settings (see Section 2.7.5.2), has been shown to alleviate vestibular symptoms and improve balance. However, for those who present to hospital with dizziness / vertigo complaints, there is no screening process to identify those with a likely non-emergent vestibular disorder compared to those without a vestibular disorder. It is postulated that improved screening for vestibular disorders in people presenting to hospital with dizziness / vertigo, who have had an emergent condition excluded, may encourage timely, accurate and cost-effective diagnosis and management of non-emergent vestibular disorders.

A vestibular screening tool is required in the acute hospital setting because:

- people presenting to ED with dizziness complaints are not managed optimally [4, 14],
- recent research focuses on algorithms to assist differentiating emergent (central) from non-emergent vestibular disorders [59, 126] however there is no process to differentiate a vestibular disorder from a non-vestibular disorder (when an emergent condition has been excluded),
- BPPV is not routinely assessed for in ED [194], despite a high prevalence rate and therefore management is not optimal [4, 14, 194, 196],

- often discharge occurs without assessment or treatment for non-emergent vestibular disorders [4],
- clinicians working in the acute hospital setting may benefit from a screening tool to screen people with dizziness [14] in order to identify those with a vestibular disorder who should be referred for VPT.

It is postulated that identification and referral of people with a non-emergent vestibular disorder is required in the ED / AME setting so that vestibular physiotherapists can provide assessment and treatment. It is not practical for all people with dizziness, including from a non-vestibular cause, to undergo a full vestibular assessment. Sourcing or developing and testing of a vestibular screening tool are warranted to assist in this process.

2.7 Treatment of vestibular disorders

This section provides a summary of the literature on treatment for non-emergent vestibular disorders, including BPPV, vestibular migraine, Meniere's disease, vestibular neuritis, unilateral and bilateral vestibular hypofunction. VPT includes repositioning techniques for BPPV, and VR. VR is detailed and evidence for VR is presented for management of unilateral and bilateral vestibular hypofunction and in older people with a vestibular disorder.

Intervention of suspected vestibular disorders may involve the general practitioner, psychologists, audiologists, occupational therapists, medical specialists such as ear

nose throat specialty and neurology, as well as physiotherapy. Treatment for vestibular disorders may include VPT, provided by physiotherapists, pharmacological management, psychological management, and / or surgery. With physiotherapy being the focus of this thesis, the evidence for physiotherapy management of people with vestibular disorders will primarily be the focus of this section. Evaluation of pharmacological management, psychology and surgery is outside the scope of this thesis.

This section will conclude with informing the reader of the limited literature on clinical effectiveness of a physiotherapy service in the hospital setting for intervention of vestibular disorders. Whilst there is some literature informing of the benefits of early intervention of vestibular disorders, there is limited research comparing the clinical outcomes of immediate and delayed intervention pathways, after presentation to hospital with a non-emergent vestibular disorder.

2.7.1 Treatment and outcomes of BPPV

BPPV guidelines [148] indicate that people with confirmed BPPV should be treated with particle repositioning manoeuvres (PRM). This section will discuss the types and outcomes of PRM for BPPV, followed by the prognosis of BPPV and the reoccurrence rates of BPPV. This section will conclude with detail of the lack and inappropriate treatment of BPPV in the acute hospital setting.

2.7.1.1 Types of PRM and outcomes for BPPV

PRM disperse debris from the canal into the utricle, where it is inactive. PRM are specific for the type of BPPV and the canal that is affected and all PRM have a sequence of head and / or trunk positioning manoeuvres as a common factor. Multiple randomised controlled trials and systematic reviews provide strong evidence that repositioning manoeuvres resolve BPPV [42, 207].

An Epley manoeuvre is a type of PRM used to specifically manage posterior canal BPPV and includes a series of four movements of the head and body from sitting to lying, rolling over and back to sitting (see Figure 2-3). During the Epley manoeuvre the person is first moved into the HPD position with their head rotated towards the side of the affected ear (shown for the left posterior semicircular canal in Figure 2-3). This places the left posterior canal in the plane of movement to allow the otoconia to move in the endolymph fluid. The movement of the person's head during the Epley manoeuvre will gradually shift the debris away from the cupula and into the common crus. Each position is held for 30-60 seconds or for twice the duration of the nystagmus. From the HPD position, the head is then slowly rotated, with approximately 20 degrees cervical extension toward the unaffected side (45 degrees to the right in Figure 2-3). The person is then rolled into the side-lie position, on the unaffected side, with the head rotated 45 degrees towards the

ground and the chin tucked towards the chest. Keeping the head rotated toward the unaffected side and with the head pitched down, the person slowly sits up.

Figure 2-3 Epley manoeuvre for treatment of left posterior canal semi-circular canal canalithiasis Benign paroxysmal positional vertigo (http://tasc.net.au/epley-maneuver/).

The Epley manoeuvre is a safe and effective treatment for posterior canal BPPV that is likely to result in improvement in symptoms [207] and has a 70-90% positive

resolution rate in one to three manoeuvres [155, 208-210]. Randomised controlled trials investigating effectiveness have short-term follow-up (4 weeks or less) and there is a lack of evidence that the Epley manoeuvre provides resolution of symptoms in the long-term [207]. There is limited research on comparisons between the Epley manoeuvre and physical, medical or surgical therapy for posterior canal BPPV [207]. However, the Epley manoeuvre for BPPV is effective for at least short-term management and has a positive effect on emotional and functional dimensions of quality of life [211], and reduces the incidence of falls [212].

There are several types of PRM for the varying types of BPPV [110]. The liberatory manoeuvre is commonly used in the management of posterior canal BPPV cupulolithiasis [213]. PRM for horizontal canal canalithiasis BPPV include the barbeque roll [214, 215], Appiani manoeuvre [216], forced prolonged positioning [217], Gufoni PRM for apogeotrophic horizontal canal BPPV canalithiasis with particles in the short arm of the horizontal canal [218]. PRM for horizontal canal cupulolithiasis include Casani manoeuvre [219], Kim manoeuvre for horizontal canal cupulolithiasis [220], and head shaking manoeuvre to convert cupulolithiasis to canalithasisis horizontal canal BPPV [221]. Anterior canal BPPV is challenging to treat [222]. Whilst there are many treatment techniques documented, there are no randomised controlled trials for anterior canal BPPV [222]. PRM for anterior canal

BPPV include the modified Epley manoeuvre [223], head hanging manoeuvre [224], Kim manoeuvre [223] and the modified Semont manoeuvre [223] for anterior canal BPPV cupulolithiasis. Brandt Daroff exercises have a low success rate and are not recommended as a first line of treatment for BPPV management [42].

2.7.1.2 Prognosis of BPPV with PRM

Prognosis for BPPV is excellent for resolution of vertigo [155, 208-210]. PRM for BPPV restore health-related quality of life in older people [79]. Whilst the prognosis of BPPV is excellent with PRM, there may be residual imbalance that requires further treatment with VR (see Section 2.7.5). There is convincing evidence from a large Cochrane systematic review and meta-analysis [137], that for BPPV, PRM are more effective in the short term than VR; although a combination of the two is effective for longer-term functional recovery [137]. Additional exercise training, with emphasis on vestibular stimulation, could improve functional gait and balance in people with BPPV who have already undergone PRM [225].

2.7.1.3 Recurrence of BPPV

There is a significant recurrence rate of BPPV (26%) [226] reported at 1 year follow-up [226]. Similarly, BPPV recurrence is 33.3% for people who presented to either ED or ear nose throat specialist out-patient clinics [227]. Follow-up prevalence studies have shown that BPPV recurrence rates are as high as 50% at 5 years [38].

2.7.1.4 Lack of and inappropriate treatment for BPPV in acute hospital setting

It has been shown that PRM are a simple bedside treatment for BPPV that is an efficacious (more than the placebo effect) treatment of acute BPPV among patients in ED [228]. However, a PRM was documented in only 0.2% of people presenting with dizziness to ED [194] and was used in only 3.9% of people given a diagnosis of BPPV [194]. This underutilising of PRM in the ED / AME setting is likely to result in people being discharged from hospital without appropriate treatment.

BPPV is not treated optimally in the acute hospital setting [105, 229]. People with dizziness diagnosed with BPPV in the ED setting are often given meclizine, a medication that is not indicated [13, 148]. Meclizine is prescribed to reduce symptoms of dizziness, nausea and vomiting and is prescribed instead of completing PRM [13]. People often receive inappropriately prescribed medications, such as vestibular suppressants, which affect the accuracy of the HPD test [195] and therefore affect treatment with appropriate PRM. Early screening, assessment and management of BPPV in ED / AME is important to provide early and appropriate assessment and treatment of BPPV [148].

Although the assessment and treatment for BPPV is documented as simple [148], the complexities and variances of BPPV may lead to a lack of accurate assessment and management in the ED setting. A simple screening tool to assess for a vestibular disorder, to encourage referral to a physiotherapist with skills in assessing

vestibular disorders, such as BPPV, may improve diagnosis and management of people presenting to hospital with dizziness due to an underlying vestibular disorder.

2.7.2 Treatment and outcomes of vestibular migraine

Physiotherapy management for vestibular migraine includes determining triggers by recording attacks in a diary, avoiding dietary triggers, behavioural changes such as stress reduction, and VR [50]. Some studies suggest VR (see Section 2.7.5) may assist people with vestibular migraine [230-232].

Non-physiotherapy treatment includes prescription of prophylactic and abortive pharmacological agents [50]. Research on the use of medications to assist vestibular migraine are currently inconclusive [115]. Treatment effectiveness for vestibular migraine requires further research [145].

2.7.3 Treatment and outcomes of Meniere's disease

Treatment of Meniere's disease comprises both conservative and aggressive treatment options. Physiotherapy intervention includes conservative treatment with VR (see Section 2.7.5). VR is recommended before and after the aggressive treatment options [233].

Non-physiotherapy conservative treatment of Meniere's disease includes steroid injections to reduce inflammation and in the setting of endolymphatic hydrops, a

low sodium diet, endolymphatic sac decompression or shunt or Menieett device [234]. Aggressive treatment may include gentamycin injections used in an attempt to preserve hearing, vestibular nerve section, or labyrinthectomy [234].

2.7.4 Treatment and outcomes of vestibular neuritis

Management of vestibular neuritis includes VR and acute pharmacological management [235]. Whilst pharmacological management is not managed by physiotherapy, it is detailed for vestibular neuritis as it has been compared with VR.

2.7.4.1 Vestibular rehabilitation for vestibular neuritis

Vestibular neuritis results in a unilateral vestibular hypofunction [132]. The primary treatment for unilateral vestibular hypofunction is VR (see Section 2.7.5).

2.7.4.2 Pharmacological management for vestibular neuritis

There is conflicting evidence for the use of corticosteroid pharmacological management for acute vestibular neuritis. It is reported that the use of corticosteroids in the acute stage of vestibular neuritis causes long-term positive results in the recovery of vestibular function and allows for improved vestibular compensation [236]. Early treatment with corticosteroids has been shown to result in a recovery rate of 62% within 12 months [132] and reduce length of hospital stay [236]. Additionally, glucocorticoid treatment in the acute stages of acute unilateral vestibular hypofunction 'leads to acute symptomatic improvement, reduced hospital stay and a reduction in the intensity of acute nystagmus' [237].

Corticosteroid therapy might enhance earlier complete vestibular neuritis resolution, however there appears to be no added benefit in long-term prognosis [238]. In contrast, there is evidence to suggest that the short-term improvements on symptoms and peripheral vestibular function from corticosteroid therapy are too small to be clinically important and do not affect symptom recovery in the long term [239].

There is also conflicting evidence that corticosteroids only improve clinical function measured by a caloric irrigation test and do not provide functional recovery for patients with vestibular neuritis [240]. Additionally, vestibular exercises have been found to be as effective as corticosteroid therapy in longer-term functional recovery as well as clinical recovery for people with vestibular neuritis [238]. Further studies are required to determine the effect of vestibular rehabilitation treatment for people presenting to hospital with vestibular neuritis.

2.7.4.3 Prognosis of vestibular neuritis

Whilst some symptoms following vestibular neuritis ameliorate rapidly after three days, even without treatment [241], about a third of people report some kind of residual symptoms after one year [242]. It is thought the reason for recovery from VR is due to plastic changes within the nervous system, known as vestibular compensation. Initial rapid resolution of vertigo in the first days after vestibular neuritis is thought to be due to vestibular compensation [132]. Vestibular

compensation includes a number of sub-processes that lead to recovery of function, substitution of lost function, and the addition of new strategies. The residual symptoms post acute vestibular neuritis, usually include symptoms of dizziness and imbalance whilst the head is moving [243]. It is thus important to identify and manage acute vestibular neuritis and resultant BPPV with VPT.

2.7.5 Vestibular rehabilitation

VR is an exercise based treatment program aimed to reduce symptoms of dizziness, vertigo, gaze instability and imbalance. VR targets the VOR as well as vestibulospinal and postural reflexes [244]. Adequate function of the VOR, neural connections between the peripheral vestibular system and the extra ocular muscles, is required for preserving stable vision during head motion, and therefore maintaining gaze and gait stability during head motion [244]. The mechanism underlying VR is compensation, which is discussed in this section, followed by evidence for VR and the limited clinical effectiveness studies utilising VR in the acute hospital setting.

2.7.5.1 Vestibular compensation

It is thought that the anatomical response to vestibular trauma is a lack of regeneration in both the vestibular hair cells and the vestibular nerve [244], therefore vestibular compensation is required. In response to a permanent vestibular lesion, it is compensation that provides improvements [244].

Compensation increases the response of the remaining vestibular system and promotes changes to the central nervous system to optimize function [244]. With compensation, the brain learns to use vision and somatosensory senses to substitute for the deficit in the vestibular system [137]. The goals of compensation are to approximate normal gaze stability and postural control under head stationary and head moving conditions, improve balance and gait, decrease falls risk, improve vision during head movements, decrease symptoms and improve quality of life [137].

To achieve compensation, vestibular rehabilitation may include education to the person, gaze stability exercises, habituation, and balance and gait training [137]. Individualised VR programs are more effective than generic-type programs [245].

Education

Reassurance about the problem and education is essential. It is important for the patient to understand the cause, the treatment options and the principles underlying the treatment. Principles of vestibular compensation and the importance of movement for this process require explanation, as many people avoid symptom provoking movements and postures [246].

Gaze stability exercises

Gaze stability exercises promote adaptation of the vestibular system thus reducing vertigo, dizziness and nausea, and improving balance and gait [137]. Gaze stability

exercises progressively promote dynamic components of the VOR, allowing for improved gaze stability during head motion [137, 247, 248].

Habituation

Habituation exercises are used to habituate people to motion sensitivity and are specific exercises based on the person's aggravating movements and aim to desensitise the intolerance to motion [249]. Habituation exercises are effective in reducing symptoms in people with vestibular disorders [250].

Balance and gait retraining

Balance and gait retraining exercises are customised to utilise and maximise the remaining vestibular function. Postural and gait re-education as well as endurance walking, are important to return to a usual functional level [251]. Substitution exercises use either individual or a combination of somatosensory and / or visual cues to either strengthen the residual vestibular function driving compensation via the central nervous system or to bias away from use of the vestibular function [137, 247-249]. Substitution exercises are utilised when there is bilateral vestibular hypo-function in particular [248] and focus on training the other somatosensory systems to provide information to maintain postural balance [248].

2.7.5.2 Evidence for vestibular rehabilitation

VR has been practised for almost 70 years [22, 252], however in the past decade, evidence related to efficacy and effectiveness has exponentially increased [253].

There is consistent evidence, including a significant number of randomised controlled trials and a Cochrane review that support the use of VR for vestibular disorders in community dwelling adults and older adults [137, 248, 254-256].

There is moderate to strong evidence that VR can increase independence, decrease vertigo, decrease ataxia and improve balance [137, 254-256]. Emerging literature indicates that the central nervous system has the competence to reweigh sensory inputs in order to correct function [253]. There is also evidence that improvements can be made with use of VR for conditions including stroke [257, 258], multiple sclerosis [259], cerebellar deficits [257], concussion [260, 261], and migraine dizziness [230, 262]. Any patient with a vestibular disorder, including from a central origin, is likely to benefit from a trial of VR [253]. There is however, a lack of evidence for VR physiotherapy programs in the acute hospital setting (see Section 2.7.5.3).

Vestibular rehabilitation for unilateral vestibular hypofunction

Moderate to strong evidence suggests that VR is safe and effective for the management for unilateral vestibular hypofunction [137, 238, 263-267]. There is moderate evidence that in the medium term, VR improves symptoms and function [268]. A systematic review undertaken by Hillier and McDonnell (2010) supports the effectiveness of VR in improving balance and mobility, preventing falls, increasing VOR gain, and improving the person's quality of life in unilateral

peripheral vestibular hypofunction [268]. Both habituation and adaptation exercise interventions (see Section 2.7.5.1), specific types of VR, are efficient in the treatment of unilateral vestibular hypofunction [269].

VR aims to stimulate the vestibular compensation processes and somatosensory and visual substitution [270]; and has been shown to reduce the incidence of disability from chronic vestibular symptoms, which develops in about 20% of people with vestibular neuritis [270]. A study completed in 2009 demonstrated that an increase in grey matter volume of the brain was related to improved functional recovery after vestibular neuritis [271]. These data suggest that improvements in vestibular function and symptoms of vertigo are related to structural cortical plasticity in multi-sensory vestibular-cortex areas in individuals with vestibular neuritis [271].

Vestibular rehabilitation for bilateral vestibular hypofunction

VR is utilised clinically to manage bilateral vestibular hypofunction [248, 253, 272-274]. There is moderate evidence supporting the use of VR to improve bilateral hypofunction [274] and clinicians should offer VR, according to recent clinical practice guidelines [248]. Further research is required to explore interventions to improve activity and participation of people with bilateral vestibular hypofunction.

VR significantly affects the recovery of the person's dynamic visual acuity in people with bilateral vestibular hypofunction. It has been theorised that VR exercises might use the centrally programmed eye movements as substitutes for the lack in

VOR [272]. Substitution exercises are utilised when there is bilateral vestibular hypofunction and focus on training the other somatosensory systems to provide information to improve postural balance [137].

Vestibular rehabilitation with older people

There is some evidence suggesting VR is effective in older people with vestibular disorders [275]. VR, combining vestibular, proprioceptive training and falls-prevention training has been shown to improve postural control, functional ability, confidence in activities of daily living, self-perceived levels of dizziness and may decrease the risk of falling among older people [276].

There is limited evidence that age is or is not a barrier to the beneficial effects of VR for people with a vestibular disorder [277]. There is some suggestion that age negatively influences the functional improvements after VR [278]. Conversely, VR has been shown to have significant improvements in older people with balance disturbances [100] and also shown to improve balance in older people with multi-sensory dizziness [100]. Additionally, VR is effective in significantly decreasing falls risk in people with unilateral vestibular dysfunction [67], although a significant proportion of older adults continue to be at risk of falls at discharge from VR [67]. VR may be considered as a treatment option for dizziness in older people however further research on effectiveness of VR with older people is required.

It is postulated that older people presenting to hospital with complaints of dizziness and vertigo would benefit from being screened for a vestibular disorder and referred to physiotherapy for VR to reduce symptoms. Identification or development of a vestibular screening tool to assist with the referral for VR and evidence for the efficacy of a VR service in the hospital setting for this purpose is proposed.

2.7.5.3 Vestibular physiotherapy in the hospital setting

In ED / AME, there is limited evidence on clinical outcomes of VPT in the acute stages of vestibular disorders. For unilateral vestibular hypofunction, recent clinical guidelines recommend clinicians should offer VR to patients with acute (0 – 2 weeks) and sub-acute (2 weeks – 3 months) unilateral vestibular hypofunction [248]. In the acute hospital population, a combination of habituation and adaptation exercises significantly improved postural stability in people with acute vestibular neuritis compared to no VR treatment [270]. Venosa and colleagues (2007) [279] reported that VR exercises (VOR adaptation exercises for unilateral vestibular hypofunction) were effective in decreasing the duration of symptoms and use of medication for people with acute peripheral vestibular disorders (excluding BPPV) [279]. Marioni and colleagues (2013) investigated the effect of a 5-week posturography-assisted VR protocol with home exercises in participants with recent unilateral vestibular dysfunction, diagnosed 2 weeks prior to the commencement of

treatment [280]. This study compared a treatment group with a non-treatment group, each with only 15 participants, to assess the effect of treatment compared to spontaneous physiological compensation. A healthy control group (10 participants) were also assessed for comparisons. Results indicated that after 6 weeks, a customized program of posturography-assisted VR and home-based exercises was superior to the spontaneous recovery group [280]. The people in the treatment group had significant improvements in most sensory measures (modified clinical test of sensory organization and balance) and motor parameters ($P<0.05$) and there were no significant differences ($p>0.05$) between the treatment group and the healthy control group in sensory and motor (limits of stability) tests [280]. People in the non-treatment group remained significantly worse ($p<0.05$) than the healthy control group in several sensory and motor parameters [280]. Whilst these two studies are supportive of VPT in the management of non-emergent vestibular disorders in the acute stage, after presentation to hospital, they do not address the clinical effectiveness of a physiotherapy-led vestibular service in the hospital setting.

There appears to evolving evidence for the clinical benefits of VPT for people with vestibular disorders presenting to sub-acute settings [137]. However, there is limited evidence on the immediate and longer-term outcomes of VPT for people presenting to ED / AME with non-emergent vestibular disorders. Furthermore,

people presenting to ED with complaints of dizziness are often not managed optimally [13]. BPPV is not managed optimally in the ED / AME (see Section 2.7.1). Physicians in ED / AME typically administer medications to relieve acute symptoms (antiemetics or vestibular suppressants), and discharge a patient from hospital without a clear diagnosis or treatment [105]. Further research is required on the clinical effectiveness of a physiotherapy-led hospital based vestibular service in managing people presenting to hospital with non-emergent vestibular disorders.

2.7.6 Immediate versus delayed intervention for vestibular disorders in hospital setting

Skilled clinicians can provide interpretative and diagnostic assessments of vestibular disorders [105] and complete balance, functional mobility and falls risk assessments and VPT treatment [137, 148]. Skilled clinicians include physiotherapists who have developed skills in this area through extensive clinical training and comprehensive professional development, often including competency-based post-graduate courses. With trained physiotherapists in the area of vestibular therapy having the capacity to assist with assessment and treatment of vestibular disorders, it is postulated that timely access to a vestibular physiotherapy service in the hospital setting may be beneficial.

There is limited research regarding the optimal time to commence physiotherapy vestibular intervention after presenting to hospital with symptoms related to vestibular disorders. There are only a few research papers found investigating

outcomes following immediate physiotherapy vestibular treatment compared to delayed commencement of treatment. Do and colleagues [227] compared an early intervention group, people with BPPV treated within 24 hours of presentation in ED, with a delayed intervention group, treated after 24 hours of presentation. After follow-up of 8-14 months, the early intervention group showed a recurrence rate of 19.7%, and the delayed intervention group showed significantly higher ($p = 0.002$) recurrence rate of 45.8% [227]. The study concluded that 'performing repositioning treatments as soon as possible after symptom onset might be an important factor in the prevention of BPPV recurrence' [227]. It has also been suggested that VPT should commence early in older people with a vestibular disorder, to avoid psychological complications, such as fear of falling [281]. Research into outcomes of immediate compared with delayed commencement of therapy is required and is incorporated into the research program informing this thesis.

The need for early referral for optimal intervention of people presenting to ED / AME has been noted for the planned research program informing this thesis. It is considered that timelier and appropriate diagnosis and management of people with vestibular disorders may improve costs (medical and societal) and quality of life. For vestibular physiotherapy assessment and treatment to commence early for people with non-emergent vestibular disorders who present to ED / AME, it is postulated that processes enabling referral are required. It is likely that use of a

screening tool in the ED / AME may assist in identifying appropriate people to refer to a vestibular service to manage this patient group. A screening tool for vestibular disorders would likely assist with timely referral and enable access to vestibular physiotherapy assessment and treatment within an acute hospital setting and post discharge from hospital.

Once a non-emergent vestibular disorder is identified, as a likely cause for presenting to hospital with complaints of dizziness, the optimal intervention pathway (i.e. immediate versus delayed) of people who present to hospital with a vestibular disorder has not been investigated. Evidence determining the clinical effectiveness of immediate vestibular physiotherapy intervention, as opposed to delayed intervention, would be helpful. It is unknown if immediate intervention of people whilst they are in the ED, achieves earlier resolution of symptoms than delayed intervention as an out-patient.

There is limited literature to guide the appropriate referral pathway of people who present to hospital with dizziness, to determine if people require assessment and intervention whilst they are in hospital or if there is any difference to clinical outcomes and health utilisation if people have delayed assessment and treatment in the out-patient setting. This thesis aims to provide clinically useful information regarding the referral and management of people who present to hospital with non-emergent vestibular disorders.

2.8 Review of vestibular questionnaires for use in the acute hospital setting

Referral to physiotherapy to commence VPT immediately may be appropriate for people presenting to hospital with vestibular disorders. Use of a vestibular screening tool in the ED / AME could assist with referral to a physiotherapy VPT service. It is necessary to source a suitable screening tool, or in the absence of such a tool, construct and establish the validity of a new tool.

The purpose of this section is to present a systematic critical appraisal of existing literature on the clinimetric properties and clinical utility of existing patient-reported questionnaires of dizziness and vertigo symptoms associated with vestibular disorders in adults. The overall aim of the systematic review presented in Section 2.9, was to determine if there was any suitable patient-reported questionnaires validated for use in the acute hospital setting with people presenting with complaints of dizziness.

The Consensus-based standards for the selection of health measurement instruments (COSMIN) framework was used to guide the content of the systematic review. The COSMIN framework is detailed in this section to understand the importance of using the framework in reviewing clinimetric properties of questionnaires. Clinical utility (relevance and usefulness of an intervention in patient care) of the validated patient-reported questionnaires was investigated, as it

is important to determine the patient-reported questionnaires appropriateness for use in the ED / AME setting. Clinical utility is therefore discussed in this section, followed by the specific aims and hypothesis of the systematic review completed for this thesis.

2.8.1 Structures used to undertake the systematic review (Paper 1)

Two structures were utilised to undertake the systematic review – the COSMIN framework and an examination of the clinical utility of identified tools for use in the ED / AME.

2.8.1.1 The COSMIN framework

The COSMIN framework is a consensus-based modular checklist 'to evaluate the methodological quality of studies on the measurement properties of health-related patient-reported outcomes' [282, 283]. The underlying basis of the COSMIN checklist is that 'studies that evaluate measurement properties of an outcome measure should be of a high methodological quality to guarantee appropriate conclusions about measurement properties of the outcome measure' [282]. A COSMIN taxonomy illustrates the relationships of measurement properties [283].

The COSMIN taxonomy includes three quality domains: (1) validity, including construct, content and criterion validity, (2) reliability, including internal consistency, repeatability and measurement error, and (3) responsiveness. Each

measurement property is evaluated separately and therefore a selection of properties can be chosen for use in a systematic review.

The taxonomy (Figure 2-4) is shown with permission (See Appendix A).

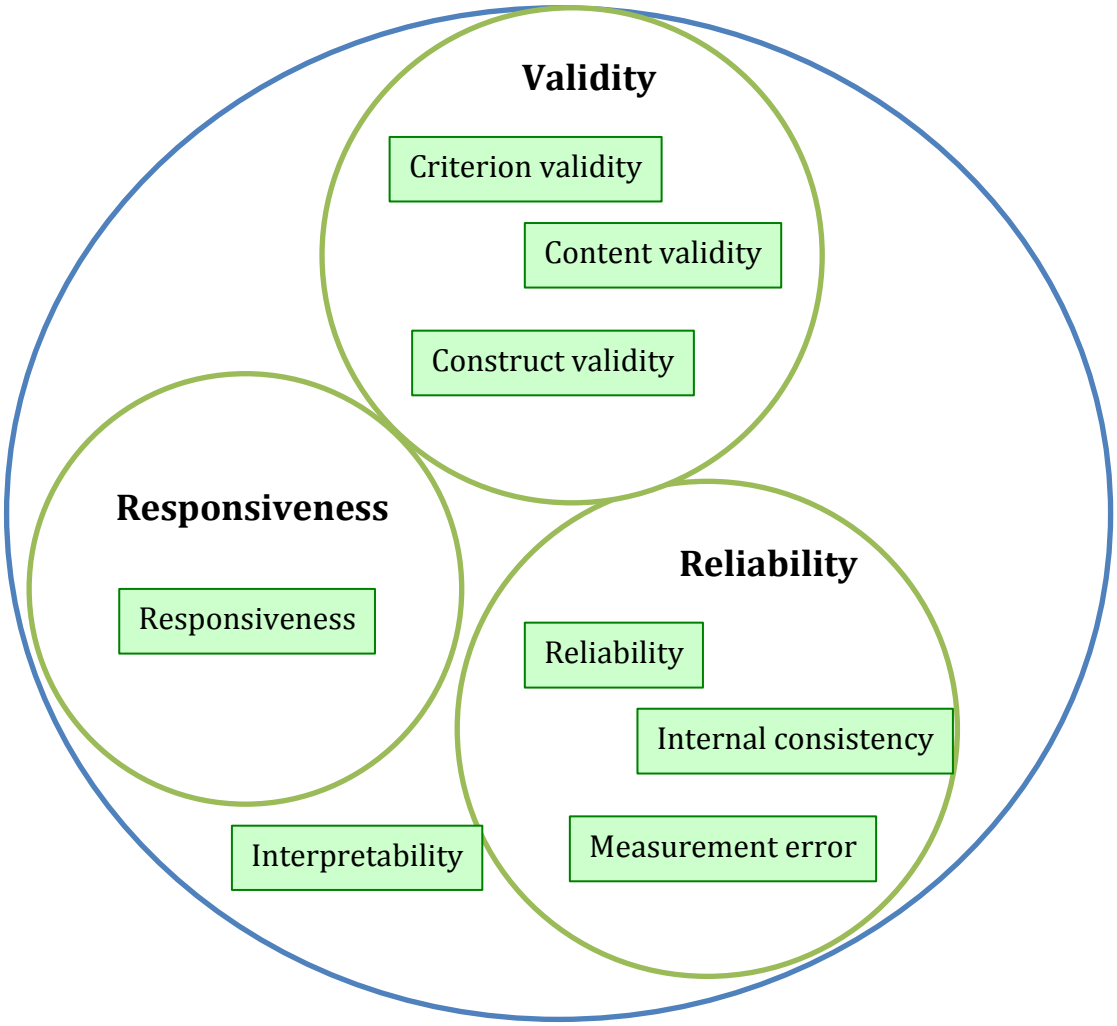


Figure 2-4 The COSMIN taxonomy of relationships of measurement properties COSMIN: Consensus-based standards for the selection of health measurement instruments [283]

The COSMIN measurement properties content validity, criterion validity, internal consistency, reliability, and responsiveness were aspects evaluated as part of the systematic review included in this thesis. These measurement properties were chosen, as they are important in determining an appropriate measure for use in screening for vestibular disorders and also for selection of clinical effectiveness studies.

According to the COSMIN definition, content validity refers to 'the degree to which the content of a patient-reported questionnaire is an adequate reflection of the construct to be measured' [284]. Content validity is important to assess the relevance of the items of the patient-reported questionnaire. Criterion validity is defined as 'the degree to which the scores of a health related patient-reported questionnaire are an adequate reflection of a gold standard' [283]. The COSMIN panel reached a consensus that no gold standard exists for patient-reported questionnaires. Most questionnaires assessing dizziness / vertigo / vestibular dysfunction have criterion validity testing, in the form of concurrent validity. Therefore, for the purpose of this systematic review, a gold standard was considered an alternative measure of dizziness / vertigo symptoms used with people with a vestibular dysfunction and has evidence of validity and reliability.

Reliability is defined as 'the degree to which the measurement is free from measurement error' [283]. Test-retest reliability and inter-rater and intra-rater

reliability were assessed using the COSMIN checklist for patient-reported questionnaires. Internal consistency is defined as 'the degree of the interrelatedness among the items' [284]. This measurement property concerns the reliability of the items to measure one construct, which is relevant to the purpose of identifying patient-reported questionnaires to screen for vestibular dysfunction in people presenting to hospital with dizziness. It is important for a measure to be tested for reliability in order to progress with clinical use and for further research purposes.

Responsiveness is the final COSMIN measurement property assessed. Responsiveness is defined as the ability of an health-related patient-reported questionnaire to detect change over time in the construct to be measured [284]. Whilst it is not essential for a screening tool in the ED / AME setting to demonstrate responsiveness, it would be ideal to utilise the same patient-reported questionnaires to assess changes in symptoms with time / after treatment.

2.8.1.2 Clinical utility of the tool for use in the ED / AME

The particular purpose or practice setting in which the measure / screening tool will be applied is an important consideration in the implementation or development of a tool. For the purposes of this thesis this is referred to as clinical utility. The second component of the systematic review was to determine if patient-reported measures

that are associated with vestibular disorders, are tested and appropriate for clinical use in the acute hospital setting (ED / AME).

Law (1987) first described criteria for evaluating clinical utility of an instrument. Criteria used for examination of clinical utility in this program of research to guide the synthesis and analyses of information [285, 286] included target population of validation study, purpose / intention of the tool, number of items and dimensions, items scaling, score administration time, and if the tool has been validated in the acute hospital setting [285, 286].

2.8.2 Aims and hypotheses of the systematic review

Table 2-3 details the specific aims and hypotheses for the systematic review completed for this thesis and the outcomes of the review are presented in Section 2.9.

Table 2-3 Aims and hypothesis of the systematic review

Specific Aims	Hypotheses
Determine the clinimetric properties (content and criterion validity, internal consistency, inter / intra-rater reliability, test-retest reliability, and responsiveness) of patient-reported questionnaires used to quantify dizziness / vertigo symptoms associated with vestibular dysfunction in adults, utilising the COSMIN checklist.	Several patient-reported measures will be identified that exhibit validity and reliability. There will be variance in COSMIN scoring for the measurement properties and the most widely utilised questionnaires may not score the best on the COSMIN checklist.
Investigate the clinical utility of patient-reported questionnaires that could be applied in the ED / AME to screen for vestibular dysfunction.	No currently available patient-reported questionnaire will be identified that is appropriate for use in the ED / AME due to being too lengthy or having a lack of validation.

Abbreviations: AME, acute medical environment; COSMIN, consensus-based standards for the selection of health measurement instruments; ED, Emergency Department.

2.9 Systematic review (Paper 1)[1]

2.9.1 Abstract

[1] Stewart, V., Mendis, M.D., Low Choy, N. *A systematic review of patient-reported measures associated with vestibular dysfunction*. The Laryngoscope, 2018. **128**: p. 971-981.

Aim / Hypothesis: Use of clinical questionnaires to assist in the screening of vestibular disorders in the acute hospital setting is needed. The aim is to detail the clinimetric properties and clinical utility of patient-reported questionnaires for quantifying dizziness / vertigo symptoms associated with vestibular dysfunction, and to determine validity and utility for screening dizziness / vertigo in the emergency department.

Data Sources: We performed a systematic review of PubMed, CINAHL, Embase, and Web of Science in May 2015.

Methods: Two independent reviewers selected studies reporting properties of patient-reported questionnaires that aim to evaluate symptomology of dizziness / vertigo associated with vestibular dysfunction. A third reviewer resolved disparities. Of 1,901 articles initially found in the database search, 58 articles and 9 patient-reported questionnaires were included.

Results: Clinimetric properties of content validity, criterion validity, internal consistency, inter- / intra-rater reliability, test–retest reliability, and responsiveness to vestibular rehabilitation are reported, and methodological quality is rated using the COSMIN checklist. Clinical utility is described in terms of target population, purpose, number of items, and whether the questionnaire was validated in the ED.

Conclusions: The Vestibular Rehabilitation Benefit Questionnaire, a relatively new tool, scored an "excellent" rating on three COSMIN criteria, and may be the best measure to address responsiveness to treatment. Questions on respective tools ranged from nine to 36, and no questionnaire was validated for use in the ED. Due to the number of questions and lack of validity, none of the questionnaires was deemed appropriate as a screening tool for dizziness / vertigo in the ED.

2.9.2 Introduction

Vestibular disorders can result in a wide range of signs and symptoms including vertigo, dizziness, and imbalance, which can impair an individual's activities of daily living, and health-related quality of life [67, 277, 287, 288]. Dizziness is defined as a sense of disorientation [2] whilst vertigo is the sensation of self-motion when no self-motion is occurring [16]. It is generally accepted that true vertigo involves a spinning sensation and usually indicates vestibular pathology [17], such as benign paroxysmal positional vertigo (BPPV) or vestibular neuritis.

Vestibular physiotherapists provide evidence based interventions to reduce symptoms of dizziness and unsteadiness [137]. Vestibular physiotherapy (VPT) includes particle repositioning manoeuvres, effective treatment for BPPV [148] and vestibular rehabilitation (VR). VR has consistent evidence of effectiveness for disorders such as vestibular neuritis and vestibular hypofunction [137], vestibular migraine [230], and central vestibular disorders [253, 257]. VR includes

compensation responses, adaptive, substitution strategies and balance / gait retraining, and can result in resolution of symptoms, improved postural balance and functional mobility [137]. There is growing clinical and research interest in diagnosis and management of vestibular disorders, however further research is required into the management of these disorders in the acute hospital setting - in particular, the emergency department (ED).

Dizziness is a common presentation, accounting for 4% of ED visits [13]. Small systematic studies of ED patients suggest that 24-43% of those presenting with dizziness have a vestibular disorder but these disorders are often under-diagnosed [13]. Screening for vestibular disorders does not routinely occur when a patient presents to hospital with dizziness complaints [4]. The use of clinical questionnaires to assist in the screening and diagnosis of vestibular disorders in the acute hospital setting is needed [4].

Patient-reported questionnaires are those that capture the subjective experience of the patient, independent of the clinicians' interpretation [289]. Such measures are being increasingly used as part of VPT intervention and outcomes [290, 291]. Questionnaires with excellent clinimetric properties are necessary to ensure accurate measurement of outcomes in clinical trials for adults with vestibular disorders. Following VPT treatment, questionnaires that assess the effectiveness of vestibular interventions on the patients' subjective experience (i.e. an evaluative

instrument that is sensitive to changes in function after an intervention) would be most useful [288]. Considering the ED context, validated questionnaires that could help differentiate patient groups, such as individuals with vestibular symptoms versus individuals without symptoms of vestibular disorder, would assist with efficient referral to VPT services. In addition, a tool that has limited questions for efficient application in ED would be most useful.

An evaluation of the methodological quality utilising a quality appraisal tool, of patient-reported questionnaires associated with vestibular dysfunction, has not been reported to date. Additionally, a review of the clinical utility in the ED / acute medical environment (AME) of these questionnaires has not been investigated. Previously completed systematic reviews on patient-reported questionnaires for vestibular disorders did not use Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) checklist to rate the patient-reported questionnaires[282] nor did they assess validity in the ED setting. Therefore, clinicians and therapists may value a critical analysis of the quality of currently available vestibular / dizziness / vertigo questionnaires for use in the ED / AME. Thus, the research questions for this systematic review are:

1. What are the clinimetric properties and clinical utility of questionnaires used to quantify dizziness and vertigo symptoms associated with vestibular dysfunction in adults utilising the COSMIN checklist?

2. Are there patient-reported questionnaires, with demonstrated validity and utility for use in the ED / acute hospital setting to screen for vestibular dysfunction?

2.9.3 Materials and methods

Identification and selection of patient-reported questionnaires and studies

A systematic search was undertaken of computerised databases in May 2015, including Pubmed, CINAHL, EMBASE, and Web of Science. The search strategy for each database is available in Appendix B. The search strategy used the medical subject heading (MeSH) terms and text words for 'vestibular', 'vertigo' and 'dizziness' in addition to specific vestibular disorders and VPT. MeSH terms and text words for 'outcome assessment' and 'questionnaires' were used to focus search results on patient-reported outcome measures. Targeted reference scanning and citation tracking of key articles was also used to identify relevant publications not identified by the initial search strategy. The literature search was not limited by study method, publication date or type. Titles of potential questionnaires were then used for a secondary search for evidence of clinimetric properties.

Two reviewers screened titles and abstracts, based on the inclusion and exclusion criteria, to identify potential questionnaires and studies to include. Conflicting results were assessed by a third reviewer and any conflicting viewpoints were discussed until all reviewers reached consensus.

Inclusion and exclusion criteria

The a priori inclusion criteria were:

(1) any patient-reported questionnaire / tool / scale that aims to evaluate symptomology of dizziness / vertigo in adults with a vestibular disorder and/or symptoms of dizziness / vertigo in adults;

(2) at least 35% of the outcome measure should evaluate symptomatology of dizziness / vertigo;

(3) the measure has published clinimetric data on validity and reliability in adults (≥ 18 years of ago) with vestibular disorder and / or symptoms of dizziness / vertigo.

Outcome measures were excluded if the tool:

(1) was not published in English (due to lack of translation services);

(2) was primarily utilised post intervention where the intervention was other than VPT;

(3) primarily assessed health related quality of life;

(4) was adapted as an outcome measure in a language (other than English) for cultural and language purposes, or

(5) assessed only one specific vestibular diagnostic group (eg. Meniere's disease).

Patient-reported questionnaires that had been shown to be reliable and valid in in other cultural or language versions as well as English, were only included once in the review. Questionnaires that primarily assess health related quality of life were excluded as symptoms of dizziness and / or vertigo is the focus in this review for the diagnostic group of vestibular disorders.

Assessment of patient-reported questionnaires

Quality Appraisal patient-reported questionnaires using COSMIN checklist

For each questionnaire included, the clinimetric properties of content validity, criterion validity, internal consistency, inter-rater and intra-rater reliability, test-retest reliability, and responsiveness to change were rated on methodological quality using the COSMIN checklist [282]. The COSMIN items were individually scored for each measurement property. A 4-point rating scale was used to classify each measure as Excellent (+++), Good (++), Fair (+), or Poor (0) and determined the methodological quality of each study (Table 2-4) [292]. A quality rating of 'Excellent' is given if all relevant COSMIN items were adequately scored. A study was rated as 'good' quality if several items were not reported, but one could assume that these issues were adequate. A rating of 'fair' quality was given if the value of the measurement property could have been underestimated or estimated in a

moderate sample size or when there were minor flaws in the design or analyses. A measure was rated 'poor' if there were major flaws in the design or statistical analyses, for example small sample size or inappropriate statistical analyses [292].

Appraisal of patient-reported questionnaires clinimetric properties

For each selected measure, data were extracted on the characteristics of populations (number of participants included, age, population tested) in which it had been tested. Where available, data were extracted on the construct / content / criterion validity, internal consistency test-retest reliability, inter-rater and intra-rater reliability, responsiveness and clinical utility of the measure.

This systematic review uniquely used definitions and guidelines outlined by the COSMIN checklist [283]. Criterion validity was considered strong when correlation with a 'gold standard' measure is ≥0.7, and moderate between 0.4-0.7 [293]. For the purposes of this review, a 'gold standard' measure was considered an alternative measure of dizziness or vertigo symptoms used with people with a vestibular dysfunction and has evidence of validity and reliability. Internal consistency was considered good when factor analysis was applied and Cronbach's alpha falls between 0.75 and 0.95 [293]. Reliability was rated good when intraclass correlation coefficient (ICC) for continuous variables or weighted Cohen's Kappa coefficient for ordinal measures is ≥0.7, with a minimum sample size of 50 participants

recommended [293]. Minimal detectable change was reported if found, as well as results for responsiveness to interventions when VPT had been undertaken.

Appraisal of patient-reported questionnaire's clinical utility

The clinical utility of the questionnaires for use in the acute hospital setting was described in terms of target population that validation was testing on, purpose / intention of the tool, number of items and subscales, items scaling and scores as an indication of administration time, and if the tool had been validated in the acute hospital setting.

Appraisal of additional studies validating patient-reported questionnaires

The primary validation study was utilised for each questionnaire for the COSMIN scoring. However, further evidence of clinimetric properties and utilisation in research was described in reference to the additional papers utilising the questionnaire.

2.9.4 Results

Flow of *patient-reported questionnaires* and studies through the review

The initial search yielded 1901 articles (Figure 2-5). Of these, 235 were removed as duplicates. Screening of 1666 abstracts led to the selection of 22 patient-reported questionnaires from 50 titles and abstracts. Additional searching for clinimetric properties of the 22 questionnaires was completed to further determine suitability for inclusion. Nine questionnaires were identified by the search strategy that met

the predetermined inclusion criteria. The combination of the original yield and additional title based searching resulted in 61 papers reporting on these questionnaires. Three papers were excluded as they were not accessible to the reviewers, resulting in a total of 58 papers being included in the systematic review.

The included measures were the dizziness handicap inventory (DHI) [294], vertigo symptom scale (VSS) [70], vestibular activities and participation (VAP) measure [295], vestibular rehabilitation benefit questionnaire (VRBQ) [296], visual vertigo analogue scale [297], vertigo handicap questionnaire (VHQ) [298], vertigo, dizziness, imbalance (VDI) questionnaire [299], vestibular disorders activities of daily living (VADL) [300], and the DHI – screening tool [301].

Ten questionnaires were excluded. The questionnaires excluded were the vertigo symptom scale short form (validity only with Norwegian version) [302], DHI short form (validity only with Italian version) [303], VAP-extended (study protocol only, no validity / reliability) [304], amer dizziness diagnostic scale (no reliability) [305], motion sickness assessment questionnaire (no reliability), dizziness beliefs scale (no reliability) [306], structured questionnaire of vertigo (no reliability) [307], dizzy factor inventory (no validity) [308], University of California Los Angeles dizziness questionnaire (validity only with Swedish version) [309, 310], visual analogue scale - dizziness and vertigo (validity only with Swedish version) [309].

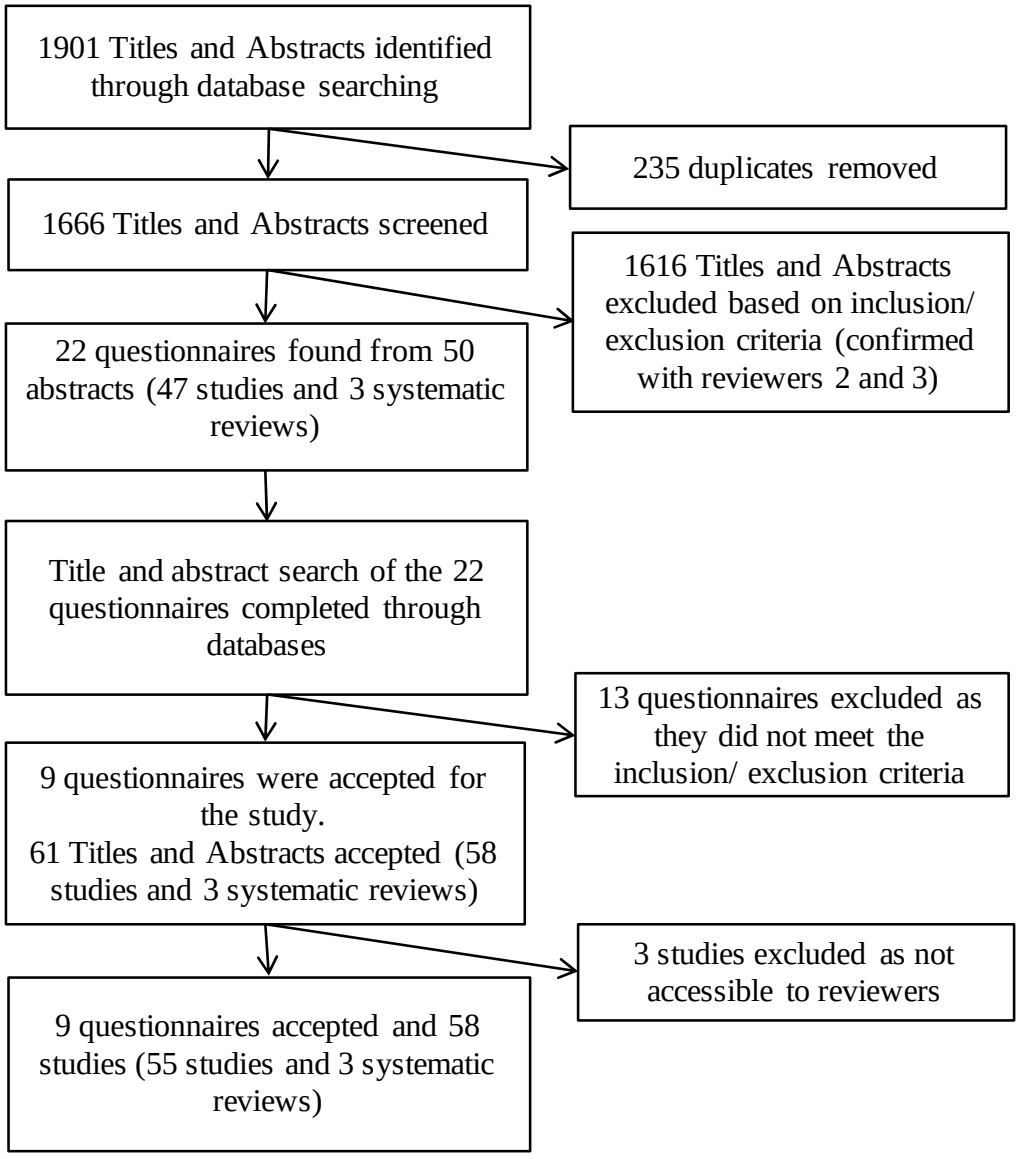


Figure 2-5 Flow diagram for the included measures of dizziness or vertigo symptoms in adults

Results of COSMIN scoring of patient-reported questionnaires

The total COSMIN scores of questionnaires for content validity, criterion validity, internal consistency, test-retest reliability, inter-rater and intra-rater reliability, and responsiveness are highlighted in Table 2-4. The specific COSMIN item scoring for each questionnaire can be accessed in Appendix C. Overall, based on the COSMIN scoring, the VRBQ, followed by the VSS and the VAP measures scored the highest. The VRBQ scored 'Excellent' on three COSMIN property measurements: content, criterion and internal consistency. The patient-reported questionnaires that scored the lowest on the COSMIN scoring were the DHI-S, VADL followed by the visual vertigo analogue scale. The VHQ, VDI and DHI, ranked in the middle for the overall COSMIN scoring range. There was no one questionnaire that was tested for all COSMIN criteria from the primary validation paper. The VRBQ and VDI were scored on five out of the six COSMIN measurement properties, whereas the DHI-S and the visual vertigo analogue scale were scored on only two. The other measures, DHI, VSS, VAP, VHQ, VADL were scored on either 3 or 4 COSMIN measurement properties. No questionnaire could be scored on COSMIN inter-rater / intra-rater reliability and only the VRBQ, VHQ and VDI were scored for COSMIN responsiveness to intervention, all of which scored 'Poor'.

Table 2-4 COSMIN scoring of patient-reported questionnaires used to quantify dizziness and vertigo symptoms associated with vestibular dysfunction in adults

Measure	Study	COSMIN-Content Validity	COSMIN-Criterion validity	COSMIN Internal Consistency	COSMIN Reliability (Inter-rater and Intra-rater)	COSMIN Reliability (Test-retest)	COSMIN Responsiveness
Dizziness Handicap Inventory	Jacobson and Newman, 1990	Excellent (+++)	Poor (0)	Fair (+)	ND	Poor (0)	ND
Vertigo symptom scale	Yardley, 1992	Fair (+)	Good (++)	Good (++)	ND	Good (++)	ND
Vestibular Activities and Participation measure	Alghwiri, 2012	Excellent (+++)	Fair (+)	ND	ND	Good (++)	ND
Vestibular Rehabilitation Benefit Questionnaire	Morris, 2008; Morris 2009	Excellent (+++)	Excellent (+++)	Excellent (+++)	ND	Good (++)	Poor (0)
Visual vertigo analogue scale	Dannenbaum, 2011	ND	Good (++)	Poor (0)	ND	ND	ND
Vertigo Handicap Questionnaire	Yardley, 1992	Excellent (+++)	ND	Good (++)	ND	ND	Poor (0)
Vertigo, Dizziness, Imbalance questionnaire	Prieto, 1999	Excellent (+++)	Poor (0)	Fair (+)	ND	Fair (+)	Poor (0)
Vestibular disorders Activities of Daily Living	Cohen, 2000	Excellent (+++)	ND	Poor (0)	ND	Poor (0)	ND
Dizziness Handicap Inventory Screening	Jacobson, 1998	ND	Fair (+)	ND	ND	Poor (0)	ND

Abbreviations: COSMIN, consensus-based standards for the selection of health measurement instruments; ND, no data.

Evidence of validity, reliability and responsiveness of primary reference of patient-reported questionnaires

Evidence of construct, content and criterion validity, internal consistency, reliability, and responsiveness of included questionnaires are detailed in Table 2-5. The questionnaires were developed via various methods. The VAP, VDI and VADL were developed from expert opinions [295, 299, 300]; the VSS, VRBQ, VHQ were constructed from patient interviews followed by factor analysis [70, 296, 311]; and the DHI constructed from case-history reports [294]. All measures except the VHQ and VADL underwent correlation testing for concurrent validity. Internal consistency was high or moderately high for all measures except the DHI-S, in which internal consistency was not measured. Test-retest reliability was also high for all measures tested. Some questionnaires had evidence for responsiveness using effect sizes (VRBQ, VDI), minimum detectable change (DHI, VAP) and clinically meaningful change (VRBQ) from the primary paper related to the respective questionnaire.

Table 2-5 Evidence of validity, reliability, responsiveness of patient-reported questionnaires used to quantify dizziness and vertigo symptoms associated with vestibular dysfunction

Measure	Study	Validity	Internal Consistency	Test-re-test reliability	Responsiveness / MDC / MICC
Dizziness Handicap Inventory (DHI)	Jacobson and Newman, 1990	Preliminary DHI was developed from case-history reports of patients with dizziness. Poor correlation between DHI total and caloric asymmetry r = 0.09, p = 0.58 (N = 37).	High: Total = 0.89; Subscales: 0.78-0.97.	High test-retest: total: r = 0.97; subscales: r = 0.92-0.97 (N = 14)	No data for responsiveness. MDC: 17.18
Vertigo symptom scale (VSS)	Yardley, 1992	Patient responses to questionnaires assessing symptoms, anxiety and handicap. Factor analysis was used to determine subscales. Moderate correlation between VSS and VHQ: r = 0.41, p < 0.001 for acute vertigo category, Weak correlation for short duration category r = 0.19.	Moderate to high: α = 0.69-0.88)	High test-retest for total and subscales: r = 0.89-0.98 (N = 44)	ND

Measure	Study	Validity	Internal Consistency	Test-re-test reliability	Responsiveness / MDC / MICC
Vestibular Activities and Participation (VAP) measure	Alghwiri, 2012	Delphi method utilised. Good face validity as determined by a group of experts. 39 of the 55 candidate items retrieved from 8 questionnaires used in individuals with vestibular disorders. Items represent only the activities and participation section of the ICF. Strong correlation between VAP and DHI total: r = 0.74. Moderate to strong correlation with DHI subscales - Functional: r = 0.71; Emotional: r = 0.65; Physical r = 0.45). Strong correlation between the VAP with the World Health Organisation Disability Assessment Schedule II (r = 0.70).	High: Total α = 0.97; Subscales: α = 0.91-0.96.	High test-retest total ICC = 0.95 (N = 58).	No data for responsiveness. MDC (95%): 0.58.
Vestibular Rehabilitation Benefit Questionnaire (VRBQ)	Morris, 2008; Morris 2009	Content validity completed with prototype questionnaire for VRBQ. Factor Analysis of VRBQ revealed 4 factors. Moderate correlation of VRBQ total with DHI total: r = 0.44. VRBQ subscales correlated with DHI subscales: r = 0.27 - 0.77.	High: Total = 0.73; Subscales = 0.74-0.92	High for total Score: ICC = 0.92 and subscales: ICC = 0.94-0.99 (N = 20)	Moderate Effect Sizes VRBQ = 0.35-0.67 (DHI effect size = 0.25-0.35 in this study). Clinically meaningful change = 7%.
Visual vertigo analogue scale (VVAS)	Dannenbaum, 2011	Moderate correlation between VVAS and DHI scores for vestibulopathy subjects: r = 0.67, p < 0.0001. VVAS severity significantly different between vestibular and non-vestibular populations (p < 0.001).	High: Total 0.94	ND	ND

Measure	Study	Validity	Internal Consistency	Test-re-test reliability	Responsiveness / MDC / MICC
Vertigo Handicap Questionnaire (VHQ)	Yardley, 1992	VHQ developed from in-depth interviews with 84 individuals with vertigo ranging in onset from less than 6 months to greater than 5 years. Individuals with episodic vertigo versus just a single episode of vertigo had worse scores on the VHQ ($p < 0.03$).	High: Total 0.95	ND	ND
Vertigo, Dizziness, Imbalance questionnaire (VDI)	Prieto, 1999	Construction from international expert opinion, interviews with patients and literature searches. Correlation with balance scale: VDI Symptoms subscale ($r = -0.57$), VDI HRQOL subscale ($r = 0.61$); correlation with SF-12 Health Survey: Symptoms subscale ($r = -0.30$-0.50), HRQoL subscale ($r = 0.57$-0.61). No correlation with vestibular questionnaire.	High: VDI symptoms 0.86; VDI HRQoL 0.92	High: VDI symptoms: 0.81, VDI HRQoL: 0.87. ($n = 50$)	VDI symptoms Effect size = 0.3-0.5, VDI HRQoL Effect Size = 0.2
Vestibular disorders Activities of Daily Living (VADL)	Cohen, 2000	Good face validity, determined by a group of experts.	High: Total 0.97; Dimensions 0 .91-0.96	High: Total r = 1, Dimensions: r = 0.87 ($n = 17$)	ND
DHI-screening (DHI-S)	Jacobson, 1998	Strong correlation between DHI-S and DHI ($r = 0.86$). Not correlated to caloric tests or rotational chair test. Moderate correlation with computerized dynamic posturography.	ND	High: Total 0.95 ($n = 45$)	ND

Abbreviations: HRQOL, health related quality of life; MDC, minimum detectable change; MICC, minimum important clinical change; ND, no data.

Evidence of clinical utility of patient-reported questionnaire in the ED

Characteristics informing clinical utility on each measure for use in the ED context are included in Table 2-6. The number of items on each questionnaire ranged from 9 items (visual vertigo analogue scale) to 36 items (VSS, VDI). It could be argued that each questionnaire would take a minimum of 5 minutes to complete for a patient, potentially longer in an acute hospital setting, should one questionnaire be adopted for this setting. No questionnaire was tested for validation in the acute hospital setting and all participants in studies were recruited from outpatient settings. Both the number of items to complete and the lack of validation in the ED setting support the view that current tools are not suited to this context.

Table 2-6 Evidence for clinical utility of patient-reported questionnaires used to quantify dizziness and vertigo symptoms associated with vestibular dysfunction

Measure (Study)	No. of items	Item scaling	Scores	No. of participants	Age of participants (y)	Sex (female %)	Participants recruited from; diagnosis / symptoms	Tested in ED / AME
Dizziness Handicap Inventory (Jacobson and Newman, 1990)	25	Yes (4), Sometimes (2), No (0)	0 - 100	63 – Development;106 - Refinement	49, (Development). 48, (Refinement)	60% Development; 62% - Refine-ment	Audiology department, seen for vestibulometric testing. Participants categorised as: Dizziness occasionally (< 12 episodes within previous year); frequently (≥ 12 episodes); or continuously	No
Vertigo symptom scale (Yardley, 1992)	36	6-point Likert scale from 0 ('never') to 5 '(very often, on average more than once a week')	0 - 136	127	Range 18 - 80	61%	Attending a neuro-otology outpatient clinic. Major diagnoses: spontaneous episodic vertigo without or with hearing loss and or tinnitus, non-rotatory vertigo, positional vertigo, single acute episode of vertigo	No

Measure (Study)	No. of items	Item scaling	Scores	No. of participants	Age of participants (y)	Sex (female %)	Participants recruited from; diagnosis / symptoms	Tested in ED / AME
Vestibular Activities and Participation measure (Alghwiri, 2012)	34	5-point scale (0 - 4) and 'Not Applicable'	Total maximum 128	58	52.60	67%	Attending balance clinic complaining of dizziness and imbalance. Diagnosed with peripheral vestibular disorders, central vestibular disorders and unspecified dizziness	No
Vestibular Rehabilitation Benefit Questionnaire (Morris, 2008; Morris, 2009)	22	7-point scale ranging from 'All of the time' to 'never' (Items 1 - 6); 'not at all dizzy' to extremely dizzy' (Items 7 - 11); 'a lot more', 'a lot less' (Items 12 - 22)	0 - 100%	155 stage 1; 124 stage 2.	ND	ND	Receiving vestibular rehabilitation at a clinic. Specific diagnoses not specified	No

Measure (Study)	No. of items	Item scaling	Scores	No. of participants	Age of participants (y)	Sex (female %)	Participants recruited from; diagnosis / symptoms	Tested in ED / AME
Visual vertigo analogue scale (Dannenbaum, 2011)	9	0 - 10 ranging from 0 ('No dizziness') to 10 ('Extreme dizziness')	For each separate VAS: 0 - 10.	102	57.6	70%	Referred for vestibular rehabilitation from otolaryngologists. Diagnosed with vestibulopathy	No
Vertigo Handicap Questionnaire (Yardley, 1992)	25	5-point scale ranging from 0 ('No handicap') to 4 ('maximum handicap')	0 - 100	100	Range 16 - 78	64%	Audiology department due to dizziness. Diagnostic categories included rotatory vertigo, positional vertigo, neck positional vertigo, non-rotational vertigo, miscellaneous	No
Vertigo, Dizziness, Imbalance questionnaire (Prieto, 1999)	36	6-point Likert verbal scale from 1 ('All the time') to 6 ('Never')	0-100	130	67	69%	Recruited by GP's, neurologists; and ENT specialists. Diagnostic groups of peripheral vertigo, central vertigo	No
Vestibular disorders Activities of Daily Living (Cohen, 2000)	28	10-point Likert verbal scale 'Independent' to 'too difficult, no	1-8	93 – stage 1; 28 – stage 2	52-55	68%-74%;	Referred for vestibular rehabilitation after diagnosis of peripheral vestibular disorder with chronic vertigo or BPPV	No

Measure (Study)	No. of items	Item scaling	Scores	No. of participants	Age of participants (y)	Sex (female %)	Participants recruited from; diagnosis / symptoms	Tested in ED / AME
		longer perform'						
Dizziness Handicap Inventory-screening (Jacobson, 1998)	10	0 - 100mm range from 'No symptoms' to 'worst possible symptoms'	0-40	278	51	60%	Patients seen for balance function testing	No

Abbreviations: AME, acute medical environment; BPPV, Benign Paroxysmal Positional Vertigo; ED, emergency department; ENT, Ear Nose Throat; ND, no data; No., number; VAS, Visual Analogue Scale.

Evidence of additional studies validating patient-reported questionnaires

The DHI returned the largest number of papers for the title search and is documented as arguably the most widely utilised questionnaire for dizziness / vertigo / vestibular [291, 312]. The DHI has been tested for an association with an extensive list of other dizziness scales [295, 297] related to balance impairments [256, 313], vestibular tests [314] and balance tests [312, 315, 316]. There are many studies which show the effect of treatment (including VPT) in patients with vestibular dysfunction [73, 254, 256, 312, 317-319]. The DHI was shown to be more responsive to recovery after VPT than the quality of life measure - Short-Form survey (SF-36) – to monitor outcomes following unilateral / bilateral vestibular dysfunction [287]. Additionally, the DHI has been used with specific vestibular diagnostic groups including vestibular schwannoma [320, 321], BPPV [317, 322], peripheral unilateral vestibular dysfunction [323], vestibular neuritis [314, 324], bilateral vestibular loss [325], and migraine [262]. A review of the DHI completed in 2013 summarises the DHI's utilisation in clinical studies [312].

A study in 2013 by Saxena and colleagues (2013) found the DHI score to be a useful tool for the prediction of BPPV. They found a statistically significant association of DHI scores of greater or equal to 50 with the diagnosis of BPPV ($p < 0.01$) [322]. A five-item BPPV sub-score of the DHI was developed by Whitney and colleagues in 2005 and after investigating the sensitivity, specificity, and likelihood ratios of

identifying BPPV, found the new subscale of the DHI able to assist in predicting BPPV [326].

There are several limitations to the DHI. Studies have assessed the factor structure of the DHI and found the multidimensional nature is substantially different from the functional, emotional, physical subscales, suggested by the original authors and indicated the subscale structure is not valid [287, 327]. Nevertheless, studies utilising the DHI as an outcome measure for VPT indicate that the DHI is responsive to change post-intervention [73, 254, 256, 287, 312, 317-319].

The VADL has been shown to be more sensitive for subjects with less independence compared to the DHI [294, 328]. A follow-up study to the original VADL validation study, addressed the application of the VADL and reported only moderate correlations with the DHI ($r = 0.66$, $p < .001$) [328]. A review of the VADL in 2014, reported that the VADL has been found to do what it is intended to do: evaluate functional limitations, regardless of specific diagnosis [329]. The VADL has been utilised in several studies indicating the VADL is sensitive to change after relevant treatment for several different vestibular disorders [254, 255, 330-334]. Whilst the VADL is sensitive to change after treatment, the VADL correlates poorly with vertigo intensity and frequency [328], doesn't discriminate among diagnoses [335], and demonstrates only moderate associations with posturography for conditions 3, 5 and 6 of the sensory organisation test, ($r = -0.499$, $p = .004$) [328]. However, a more

unique finding is the correlation between the changes on the VADL and changes in functional magnetic resonance imaging during compensation of the brain [271]. The VADL was also shown to differentiate between healthy people and patients with chronic vertigo from vestibular disorders and BPPV [328].

An evaluation of the VSS for clinical application was completed in 2007 using 20 adults with peripheral vestibular disorders [336]. Symptoms reported in diaries by the subjects were compared with the content of the VSS and found the VSS to have an adequate base but may need to be developed to evaluate care and treatment [336].

The VSS and VHQ have been utilised together in two studies. One study investigated dizziness symptom severity and the impact on daily living as perceived by patients ($n = 99$) suffering from peripheral vestibular disorder [337]. The second study was a longitudinal study in adults with recurrent dizziness / vertigo / dysequilibrium determining factors contributing to impairment [306]. The VHQ [298] was developed to investigate factors influencing handicap related to dizziness. In the primary validation paper on the VHQ, a small sample ($n = 14$) of VHQ scores decreased ($p = 0.04$) in participants who improved after 6 months. However, results of a clinical trial of VPT suggest the VHQ is not reliably responsive to change [338]; limiting its potential as a useful measure of treatment outcome. Despite not being reported in the primary VHQ paper, the test-retest reliability for the VHQ was

reported as 0.97 when tested after 24hours (n = 13) in a paper validating the VSS [339].

There were limited studies yielded by the search for this review when the VRBQ, VVAS, VDI, DHI-S and the VAP are considered. The VRBQ and the VAP were developed relatively recently in 2008 and 2012 respectively. The VAP aims to evaluate the extent to which vestibular disorders limit activities and restrict participation. Further research may be underway on the VAP as a study protocol was published in 2013 on the development of an extended and shortened version of the VAP by applying the Rasch unidimensional measurement model [340].

2.9.5 Discussion

This is the first systematic review to assess patient-reported questionnaires of dizziness / vertigo utilising the COSMIN checklist. The VRBQ clearly scored the highest on the COSMIN rating scale of property measurements and is arguably the best questionnaire for the purpose for which it was specifically developed - to address treatment outcomes of VPT. The VSS scored the second highest on the COSMIN property measurements overall. The VSS was developed to measure vertigo severity uncontaminated by symptomatology caused by anxiety [70]. However, there are some limitations that will be discussed later if only the COSMIN score is taken into account when assessing the patient-reported questionnaires.

Several questionnaires, including the VAP, VRBQ, VVAS, and DHI-S, provided evidence of varied or high correlations with the widely utilised DHI, frequently considered as the gold standard tool. Whilst the COSMIN guideline reports that no true gold standard exists for questionnaires, a 'reasonable gold standard' is accepted [282]. For the purposes of this study, the definition of a 'reasonable gold standard' meant the DHI was accepted as this benchmark.

Whilst the DHI was utilised as the criterion standard, it is important to acknowledge that the DHI is flawed; the DHI is poorly correlated with caloric symmetry [294], reducing the credibility of the COSMIN criterion validity scores. For future studies, it is recommended that the VRBQ be accepted as the 'gold standard' criterion for both determining outcomes and for testing the associations between patient-reported questionnaires that aim to evaluate symptomatology of dizziness / vertigo associated with vestibular dysfunction.

All questionnaires included in this study, except the VVAS and the VHQ, reported on test-retest reliability. However, the use of test-retest reliability of a patient-reported questionnaire of dizziness / vertigo may be considered problematic because of the fluctuating nature of dizziness / vertigo symptoms. An alternative, which was suggested in the VHQ validation paper, is to assess sensitivity to change / responsiveness post-intervention [298].

The COSMIN guideline identifies that the use of effect sizes are inappropriate measures of responsiveness and studies are therefore scored 'Poor' based on having an important 'flaw' [282]. When investigating the VRBQ, several questionnaires were compared to give evidence for the relative responsiveness of the measures [296]. However, relative responsiveness is only helpful if there is a hypothesis being tested which includes the expected magnitude of the treatment effect. Such a hypothesis was lacking in the VRBQ study. The VDI questionnaire also utilised effect sizes as a measure of responsiveness and therefore both measures scored a 'Poor' on the COSMIN responsiveness measurement property based on having an important flaw - use of inappropriate statistics.

COSMIN defines responsiveness as the ability to detect change over time in the construct to be measured [282]. A correlation between change scores is the preferred method for comparing changes in the questionnaire with changes in a gold standard. Whilst the COSMIN guideline reports that no true gold standard exists for questionnaires, the ability of a measure to change over a particular pre-specified period when a known efficacious treatment can be applied could be useful in determining responsiveness [341]. For people with a vestibular disorder, there is a consistent body of evidence, including a large number of randomised controlled trials that support the efficacy of VPT [137, 233, 257]. Therefore, highlighting the use of patient-reported questionnaires in studies indicating sensitivity to change

after VPT is relevant. Despite the DHI having a mixture of excellent (+++), fair (+) and poor (0) scores based on the COSMIN scoring system, the title search produced the largest amount of supporting evidence for sensitivity to change after appropriate treatment, and for correlations between the DHI and other tests associated with vestibular dysfunction.

The COSMIN scoring system was developed following an international Delphi study focusing on the standards required in the development and evaluation of health-related questionnaires. However, there are some limitations to the COSMIN checklist when evaluating patient-reported questionnaires. A measurement property is scored as Poor (0) if statistical tests other than those recommended are used or if subject numbers are less than 50 subjects. The DHI was scored 'Poor (0)' for both the criterion validity and test-retest reliability due to sample size.

To identify a patient-reported questionnaire associated with vestibular dysfunction, that is valid, reliable, and responsive to change when patients undergo vestibular rehabilitation, it is recommended that the COSMIN checklist is utilised to inform the quality of the clinimetric properties of the measure. In addition, when selecting a measure for use in a specific setting or with a specific vestibular diagnostic group, the setting and diagnostic group utilised in the validation study should be understood so that the utility of the measure can be determined.

A unique secondary aim of this study was to investigate the clinical utility of patient-reported questionnaires for use in the acute hospital setting, as a screening tool identifying vestibular disorders. There were no questionnaires of dizziness and vertigo investigated in this study that were developed for the purpose of being utilised or validated in the acute hospital setting. It is also evident that the tools were developed with the intent of being a comprehensive evaluation of dizziness / vertigo symptoms. As such, the number of items (questions) in each measure is relatively high (ranging from 9 to 36), and is considered too many for use in an ED, where time is of an essence. On this basis, we argue that there is a need for a short questionnaire to be developed and validated in the acute hospital setting such as the ED. A validated questionnaire for use in the ED would enable screening of patients presenting to hospital with dizziness / vertigo complaints for a vestibular dysfunction, and referral of patients for VPT.

2.9.6 Conclusion

This review has provided a detailed summary of the validity, reliability, responsiveness and clinical utility of questionnaires used to quantify dizziness and vertigo symptoms associated with vestibular dysfunction in adults, utilising the COSMIN checklist. The VRBQ scored the highest on the COSMIN checklist and arguably may be the best questionnaire to address treatment outcomes in patients with vestibular dysfunction. The DHI whilst scoring lower on the COSMIN checklist,

should be considered for use in VPT settings as it is widely utilised and demonstrates robust clinimetric properties. No patient-reported questionnaires were deemed appropriate as a screening tool in the acute hospital setting. This review may prove helpful to clinicians and researchers when deciding which questionnaire to select depending on the purpose for which it is intended.

2.10 The need for further research

The review of literature reported in this background chapter provided evidence that vestibular disorders are highly prevalent in the population, frequently present to the acute hospital setting and require appropriate referral and management. The impact of vestibular disorders on individuals and society has also been shown to be high and may lead to a negative sequalae of ongoing dizziness and vertigo symptoms, balance and gait disturbance, fear of falling, falls and fall related injuries. Treatment for vestibular disorders, in the form of VPT performed by trained physiotherapists has been shown to be effective in out-patient / community settings.

Over the past decade there has been a significant increase in research involving physiotherapy and vestibular disorders, however there are many gaps in the literature, worthy of further investigation. The literature reports on an under diagnosis and mismanagement of vestibular disorders in the acute hospital setting however, there is minimal literature on screening for a vestibular disorder in this

setting. The HINTS test is a bedside clinical examination to assist in identifying central disorders such as stroke in people who present with vertigo. There appears to be a thought amongst clinicians in the ED setting that once an emergent central disorder is eliminated in people presenting with vertigo, discharge is appropriate, often without referral for further assessment and management. This may be confounding the misdiagnosis and mismanagement of people with a non-emergent vestibular disorder. The need for a screening tool to assist in identifying non-emergent vestibular disorders in people with dizziness in the ED / AME setting has been identified as an important gap in the literature. Such a tool may assist with referral of people with dizziness to a hospital-based vestibular physiotherapy service, overall improving diagnosis and management.

The primary gap identified through the systematic review (see Chapter 2.8), was the lack of an appropriate screening tool for use in the acute hospital setting to screen people presenting with dizziness for a vestibular disorder. The systematic review provided the rationale for the construction of a new vestibular screening tool and its validation in the ED / AME to assist with screening people for non-emergent vestibular disorders. While the main application of the COSMIN checklist was for systematic reviews of measurement properties, the checklist may also be used to aid in the design of a validation study of a new screening tool [282]. The COSMIN taxonomy and checklist were therefore used in this research program where the

construction, development and validation of the VST is presented (see Section 4.2 and 4.3)

A vestibular screening tool assists in referral of appropriate people to a physiotherapy vestibular service in a hospital setting. Whilst VPT has supporting literature in the context of community settings, the clinical efficacy of such services within the hospital sector are lacking. Therefore, the secondary gap identified in the literature is the clinical effectiveness of a hospital-based, physiotherapy vestibular service. Additionally, there is a lack of research informing appropriate clinical referral pathways to a physiotherapy vestibular service, for people identified as having a vestibular disorder in the acute hospital setting. It is currently unknown if people, presenting to hospital with dizziness complaints and identified as having a vestibular disorder, should be managed immediately in the ED / AME, or referred to an out-patient service, where there may be some delay to receiving a diagnostic assessment and management, and if a delayed intervention affects clinical outcomes.

There are several other gaps in the literature that have been identified:

- Frequency of falls post hospital presentation with a vestibular disorder;
- Societal and personal burden of dizziness and vestibular disorders in Australia;
- Representation and readmission rates post discharge from hospital after a vestibular disorder hospital presentation.

However, the primary and secondary gaps identified are the focus of this thesis, as they will build the ability to further research the remainder of these important research topics.

2.11 Research aims and hypotheses

The broad aim of the thesis is to improve the service model of care (screening and management) for people presenting to hospital with a non-emergent vestibular disorder. The goal is for this research thesis to have a significant clinical impact on the processes within the hospital setting in regard to managing people who present to hospital with complaints of dizziness. If people can be screened and referred in the ED / AME, and receive clinically effective treatment from a physiotherapy vestibular service, the overall diagnosis and management of this patient group could be improved.

The thesis is divided into two phases to achieve the overall aim of the thesis. The primary research aim of Phase one, is to construct a valid and reliable screening tool to identify non-emergent vestibular disorder in the acute hospital setting. Table 2-7 details the specific aims and hypotheses for this phase.

Table 2-7 Aims and hypotheses of Phase one of the research program

Specific aims	Hypothesis
Develop a new tool (VST) for application in the acute hospital setting, to screen for non-emergent vestibular disorders when people present with dizziness and enable referral of appropriate people to vestibular physiotherapy.	The VST will be a clinically useful tool to use with people presenting to hospital with dizziness. It is postulated that scores on the VST will indicate the likelihood of a non-emergent vestibular disorder and therefore the VST score would be valid to use to help decision making related to referral of appropriate people to the hospital based physiotherapy vestibular service for a diagnostic assessment and management.
Establish construct validity of the VST.	VST items will be unidimensional and will demonstrate internal consistency allowing the summing of items to a total score.
Determine content validity of the VST	The items selected for inclusion in the VST will be supported by experienced clinicians in the field of vestibular rehabilitation.
Determine discriminative validity, sensitivity, specificity of VST for identifying vestibular disorders	A cut-off VST score will be determined, indicating presence of a likely vestibular disorder requiring further assessment and treatment by a physiotherapist.
Establish criterion (concurrent) validity of the VST by testing the association with the DHI (total score and sub-category) in people with dizziness referred directly from the Emergency Department / acute medical environment to the vestibular service at	The VST will be highly associated ($r \geq .7$) with the DHI total score thus determining concurrent validity of the VST with the DHI, across the 3 assessment points.

initial, discharge and follow-up assessment.	
Demonstrate inter-rater and intra-rater reliability of physiotherapy assessors administering the tool.	Inter-rater and intra-rater reliability will be high when physiotherapists administer the VST.
Test the VST for internal responsiveness following VPT.	The VST will show statistically significant improvement ($p < 0.05$) in dizziness symptoms after VPT intervention (initial to discharge assessment), a requirement for internal responsiveness, and scores will remain the same at follow-up, 3-months after the discharge assessment ($p < 0.05$). The VST could be used as a measure of change in vestibular disorder symptoms.
Examine the external responsiveness of the VST, using the DHI as the reference measure, and determining correlations between changes in VST and changes in DHI total and sub-category scores from initial to discharge assessments and between discharge and follow-up assessments to determine the degree one measure changed compared to the other at different time points.	The VST will demonstrate external responsiveness to change in dizziness impairment, in line with the DHI, across the continuum of care. High associations will be found between changes in VST scores and changes in DHI (total and physical sub-category) scores from initial to discharge assessment, after vestibular rehabilitation intervention; and from discharge assessment to the three month follow-up assessment. There will be moderate associations between changes in VST scores and changes in functional and emotional DHI sub-category scores. The VST could be used as a measure of change in vestibular disorders, as compared with DHI scores.
Investigate if a clinically important change could be identified for the VST.	A 1 to 2-point change in the VST score will indicate a clinically important change.

Abbreviations: DHI, dizziness handicap inventory; VST, vestibular screening tool

There is limited evidence concerning the effectiveness of a physiotherapy vestibular service in a hospital setting. The first aim of Phase two of the research thesis is to determine clinical effectiveness and outcomes of people seen in a physiotherapy-led hospital-based vestibular service by determining short-term (on discharge) and longer-term (3 months post discharge) outcomes after completing VPT.

There is also a lack of evidence investigating the effect of a delay to vestibular intervention (assessment and management) on clinical outcomes in people presenting to hospital with a vestibular disorder. It is common practice for people to have a delay in physiotherapy vestibular intervention, due to a lack of service in the acute setting and therefore being placed on an out-patient waitlist, post discharge from hospital.

A new physiotherapy-led vestibular model of care has been developed to provide services to the acute hospital setting (as well as provide out-patient services). The new model of care includes immediate physiotherapy vestibular intervention for people with dizziness presenting to hospital with a likely vestibular disorder. The vestibular service includes assessment and treatment in ED and other acute hospital settings, with follow-up sessions in a hospital based out-patient setting. The clinical effectiveness of the physiotherapy-led hospital-based vestibular service warrants investigation. The second aim of Phase two, is to test the clinical outcomes of people immediately referred to the physiotherapy vestibular service, receiving assessment

and treatment whilst they are in hospital; compared with those referred through a waitlist, delayed intervention pathway, receiving treatment post discharge from hospital, as an out-patient. Table 2-8 details the specific aims and hypotheses for Phase two of the research program.

Table 2-8 Specific aims and hypotheses of Phase two of the research program

Specific aims	Hypothesis
Provide a profile of people referred to a hospital-based physiotherapy vestibular service following presentation to hospital with dizziness (Age, clinical diagnosis, falls history, VST scores, DHI scores, ABC-6 scores, balance and mobility measures)	It is hypothesised that people referred to this service will: - Be older adults (average over 60 years of age); - Present with a range of vestibular disorders, with BPPV as the most prevalent vestibular disorder; People grouped as having a vestibular disorder will have: - Moderate to severe self-reported dizziness impairment, as measured by the VST (≥ 4 / 8) and DHI (≥ 60 / 100); - Significant functional limitations, with an increased risk of falling and poor community ambulation, as revealed the clinical measures TUG, FGA, static balance feet together eyes closed, 10MWT with and without head turns. - Moderate balance confidence (ABC-6) scores between 50-80 / 100; - Many participants will self-report falls in the previous 12 months; - Balance and mobility measures will indicate current falls risks The non-vestibular group will be within normal ranges of measures.

Determine the clinical effectiveness of the physiotherapy-led hospital-based vestibular service by determining short-term (on discharge) and longer-term (3-months post discharge) outcomes after completing VPT. Outcomes of interest include subjective rating scale of improvement, self-perceived dizziness disorder (VST and DHI); balance confidence (ABC-6); measure of vestibular hypofunction (DVA); balance/mobility disorder as measured by functional measures (FGA, TUG, 10MWT, 10MWT with head turns, static balance feet together eyes closed); symptom resolution.	It is hypothesised that 95% of people will have significant benefits after VPT treatment. It is hypothesised that the hospital based vestibular service will produce clinically effective results after VPT treatment. Significant improvement of symptoms by discharged, maintained longer term; - A low number of treatment sessions (3 on average) will be required to achieve discharge assessment results; - Significant reduction in self-perceived symptoms as measured by the VST and DHI after VPT and maintained 3-months after discharge; - Improvement in balance confidence measure (ABC-6) after VPT intervention, maintained longer term; - Clinically important change in DHI and VST scores by discharge; - Improvement in DVA to normal range (less than 3 lines difference); - At discharge following VPT, people will have a low risk of fall with higher FGA scores recorded above scores (> 22 / 30) predictive of prospective falls; - Clinically and statistically significant improvement in balance and mobility measures to normal ranges; - A moderate recurrence rate seen in the 3-month follow-up stage for the clinical diagnostic group of BPPV, in line with literature [342].

	It is hypothesised that by the discharge assessment, after VPT intervention, scores on all measures will be normal and will remain within normal limits at the 3-month follow-up assessment. Overall there will be a high level of longer-term benefits.
Compare clinical outcomes and effectiveness (short-term and longer-term) for immediate and delayed intervention pathways with people referred to the physiotherapy-led vestibular service, to inform best service delivery model in the acute hospital setting for people presenting to hospital with vestibular disorder.	It is hypothesised that people, who receive immediate physiotherapy vestibular intervention compared to those who have delayed intervention, will: - Receive intervention quicker; - Have faster resolution of symptoms from time of presentation to hospital; - Require fewer treatment sessions however the difference may not be statistically significant; - Achieve comparable clinical measures after VPT treatment at discharge, and at the 3-month follow-up assessment.

Abbreviations: ABC-6, activities specific balance confidence short form; BPPV, benign paroxysmal positional vertigo; DHI, dizziness handicap inventory; DVA, dynamic visual acuity; FGA, functional gait assessment; TUG, timed up and go; VPT, vestibular physiotherapy; VST, vestibular screening tool; 10MWT, ten metre walk test.

Chapter 3 Methodology and design

3.1 Introduction

In this chapter, the principal research frameworks guiding the design of the research program are presented. The methodology and design is divided into two phases to achieve the overall thesis aim to improve the service model of care (screening and management) for people presenting to hospital with a non-emergent vestibular disorder:

1) Phase one: Construction and validation of the VST for use in the ED / AME; and,
2) Phase two: Establishing the overall clinical effectiveness of a vestibular physiotherapy service in the hospital setting.

The primary aim of Phase one is to construct a valid and reliable screening tool to identify non-emergent vestibular disorders in the acute hospital setting. The specific aims of Phase one include establishing the clinimetric properties of the new tool, including validity, internal consistency, reliability, and responsiveness. The rationale for the research protocol of Phase one is presented in Section 3.2, including justification for the selection of validation studies of the VST and the specific statistical approaches used for analysis.

The primary aim of Phase two of this thesis is to determine clinical effectiveness and outcomes of people seen in a physiotherapy-led hospital based vestibular service by determining short-term (on discharge) and longer-term (3 months post discharge) outcomes after completing VPT, and testing the clinical outcomes of people immediately referred to the physiotherapy vestibular service, compared to a delayed intervention pathway. The rationale for the research protocol used in Phase two is presented in Section 3.4.

Finally, the selection of measures for Phase one and Phase two of the research program is discussed in detail in Section 3.5. Three types of measures were required; vestibular diagnostic assessment measures, questionnaires related to dizziness, and balance confidence, and objective measures of balance and mobility.

3.2 Phase one: Construction and validation of the VST for use in the ED / AME (Research methodology underpinning Papers 2 and 3)

As outlined in the background chapter, the need for a screening tool to assist in identifying non-emergent vestibular disorders in people with dizziness in the ED / AME setting has been identified as an important gap in the literature. Such a tool may assist with referral of people with dizziness to the hospital-based vestibular physiotherapy service, overall improving diagnosis and management. The systematic review completed for this thesis (see Section 2.9) confirmed the lack of

suitable screening tools available for use in the acute hospital setting to identify vestibular disorders in people with dizziness.

In this section, the process of constructing the VST and justification of validation studies to establish the validity, reliability and responsiveness of the VST is discussed. Specific details of the research design, ethical approval, setting, participants, measures, study protocols, and statistics applied can be found in Paper 2 and Paper 3 (see Section 4.2 and 4.3). Also detailed in Paper 2 (see Section 4.2) is the process used in the construction and piloting of the VST for use in ED / AME to screen for non-emergent vestibular disorders when people present with dizziness complaints.

It is important that a new screening tool, such as the VST, demonstrates adequate measurement properties before being utilised clinically or for research. Validation research tests the extent to which an assessment is measuring what it intends to measure [282]. Screening tools are used in several ways and whether or not they can be used for a specific purpose depends on whether the tool has been validated for that purpose [343]. Therefore, the focus of validation testing is the use for which a screening tool is required.

Validation research has three principal types of measurement properties: validity, reliability and responsiveness [284]. In this thesis, the methods of validation planned for the VST were construct validity, criterion validity (concurrent validity),

content validity (agreement of clinical experts), internal consistency, reliability (inter-rater and intra-rater), responsiveness to change and establishing the minimal clinically important difference score. These methods of validation are discussed in the context of the research program underpinning this thesis in the following sections.

3.2.1 Validity

Validity has been defined as 'the degree to which we can draw conclusions about an attribute for an individual, from scores on an outcome measure, when used with a certain group of people, for a particular purpose' [343]. As therapists, we need to understand if items included in a screening tool sufficiently characterise the areas they are designed to measure [285]. A screening tool is thought to have validity when research determines that it measures what it intends to measure. There are many types of validity and the COSMIN framework has developed definitions for each type [283]. A number of these clinimetric properties were applied in this research program.

3.2.1.1 Construct validity

Although the exact definitions and meaning of validity types is not unanimous, there seems to be agreement that construct validity is the focus of validity [344]. Construct validity 'reflects the ability of an outcome measure to measure the underlying concept of interest to the clinician or researcher' [345, 346]. One

method to test construct validity is by using the groups method. This approach, utilised in the construct validity of the VST, is based on the assumption that if you utilise the screening tool for two differing groups of subjects, the resulting test scores should differ [345, 346]. In validating the VST, this principle was applied in this research program; the two groups assumed to differ were those with a vestibular disorder and those without, despite all presenting to hospital with symptoms of dizziness and / or vertigo.

To analyse the VST's construct, the Rasch measurement model, along with principles component factor analysis and Cronbach alpha were completed to determine the unidimensionality of the VST. The occurrence of more than one dimension within a screening tool poses a restriction to the utility of that screening tool [347-349]. When a measure is unidimensional, items can be summed to achieve a total score. Binary regression model was used to determine the internal consistency of the VST, helping determine the construct validity of the VST. The unidimensionality and the internal consistency support summing of the items for a total score. The ability to sum the VST items to a total score is important for the utility of this tool in the acute hospital setting. A total score can then be used to determine discriminative validity in identifying a vestibular or a non-vestibular disorder. Clinically, a total score is relevant to provide assistance to clinicians when deciding if the person is more likely to require a vestibular assessment and management.

The fewest number of items without affecting construct validity was a priority in constructing the VST. The location for the VST to be used is the acute hospital setting where clinical time to complete a screening tool needs to be minimal and therefore few items comprising the VST is important. When attempting to construct a new tool with the fewest number of items without compromising the construct, Rasch analysis, regression model and factor analysis are taken into consideration to determine which items could be omitted from the tool as it is being constructed.

Item response theory and Rasch analysis

Item response theory is a statistical process commonly used to investigate the internal construct validity of a tool. Rasch analysis is a one-parameter statistical model based on item response theory models [350, 351] and provides information about a tool's measurement and scaling properties by comparing the actual and predicted responses to items [352, 353].

One important expectation of the Rasch model is of scale unidimensionality; that is, it measures one trait [354]. If the items on the VST fit the Rasch model and there are no anomalies that threaten the validity, then the raw VST item scores can be summed to achieve a total VST score. If they do not fit the Rasch model, then Rasch converted scores would need to be used instead of the raw scores [354]. Confirming unidimensionality validates the summing of items to provide an overall score.

Summing item scores can be useful to combine information about several factors into an overall summary of the underlying construct.

One advantage of a Rasch analysis is the ranking of items from easiest to most difficult along a hierarchy, allowing important information about scaling and score weights for each individual item [350]. The lower weighted items could be considered for removal from the tool during the construction phase, as they contribute less to the construct that the higher weighted items. For the VST construct, empirical evidence of item / s that contribute the least to the overall score is valuable in deciding if any item / s could be omitted from the tool, without compromising the construct.

Statistics testing the fit of the data to the Rasch model, known as "fit statistics", determine how well the data matched what was expected by the model. Overall item fit and person fit statistics can be said to "misfit" with the model expectancies, raising concerns of the validity of the measurement item / s. When the response pattern to the measurement test in question corresponds with or does not diverge significantly from the anticipated response pattern, the items fit the Rasch measurement model and comprise a true Rasch scale [355]. Checking for overall misfit in individual items of the measurement scale is important as identifying and removing individual items that are misfit may improve the overall fit of the scale to the Rasch model.

Regression model

A binary regression model was also completed to further determine if any items could be omitted from the tool. A binary regression model is a logistic regression in which the outcome variable has exactly two categories [356]. Binary logistic regression is 'a statistical analysis that determines how much variance, if at all, is explained on a dichotomous dependent variable by a set of independent variables' [356]. Non-significance of an item ($p > 0.05$) indicates it is not a significant independent predictor of having / not having a vestibular disorder.

The VST item/s with the lowest logit value on the Rasch analysis and the VST item / s with non-significance from the binary regression analysis could be omitted from the VST. Reducing the VST to its smallest valid form is clinically relevant to reduce the time taken to perform the VST in a busy clinical setting such as the ED / AME.

Factor analysis

Unidimensionality is measured by factor analysis using residual correlations among the items [348, 354]. Factor analysis is 'a multivariate technique for identifying whether correlations between a set of observed variables stem from their relationship to one or more latent variables in the data' [356]. Factor analysis identified whether the VST items stem from their relationship with one (unidimensionality) or more variables with p level set at 0.05.

3.2.1.2 Content validity

Content validity is the degree to which the content of the health-related screening tool or measure is an adequate reflection of the construct being measured [284]. In relation to this study, content validity was determined by testing the consensus of a panel of clinical experts who are experienced vestibular physiotherapists. On a Likert scale of 0 to 10, the level of agreement / disagreement of the appropriateness of each item being indicative of a vestibular disorder was rated [357, 358].

Cronbach alpha determined the level of agreement of the experienced clinicians for each VST item. Values of 0.8 or higher from Cronbach alpha analysis are acceptable values [343]. Additionally, a difference between ratings of VST items, from the experienced clinicians was assessed for statistical significance at a p value of ≤ 0.05 (See Paper 2, Section 4.2.3).

3.2.1.3 Discriminative validity

Discriminative validity is often used to support the construct validity of a test. It reflects whether an assessment measure accurately detects differences between groups that are hypothesised to score differently. Based on the results from the Rasch analysis and the binary regression analysis, VST items were considered for removal, with three (3) versions of the VST developed for further testing. Thus, a 3-item, 4-item and 5-item version of the VST was tested for discriminative validity in identifying a vestibular disorder / non-vestibular disorder. Accordingly, receiver

operating characteristic (ROC) curves were used to calculate the Area Under the Curve (AUC), sensitivity, specificity, true positive, true negative, false positive, false negative, positive predictive value and negative predictive value. The AUC was used to evaluate the effectiveness of each individual VST item and the total VST scores, in identifying a vestibular disorder or a non-vestibular disorder.

Sensitivity and specificity

The sensitivity and specificity and likelihood ratio are the statistics used to describe the utility of diagnostic tests in clinical settings [359, 360]. Sensitivity refers to how likely people are to have a positive result on a measure if they have the disease [359]. The sensitivity of a measure refers to the capability of the measure to accurately distinguish those people with the condition [359]. A measure with 100% sensitivity recognises all people with the disease. A measure that has 80% sensitivity identifies 80% of people with the disease (true positives) however 20% go unnoticed (false negatives). Specificity refers to how likely people are to have a negative test if they do not have the condition [359]. The specificity of a clinical measure refers to the capability of the measure to accurately identify those people without the disease. A measure deemed to have 100% specificity accurately identifies all people without the disease. A measure with 80% specificity accurately identifies 80% of people without the disease (true negatives) however 20% of people are identified as having the disease when they do not have the disease (false

positives). Whilst it would be ideal to have a diagnostic test with high levels of sensitivity and specificity, this is not possible since there is a trade-off between sensitivity and specificity. As sensitivity increases, specificity decreases and vice versa [361].

Sensitivity and specificity of each VST version was calculated utilising the ROC curve coordinates, to determine the optimal cut-off score. The score with the highest sensitivity without compromising a high specificity determined the cut-off score for the VST. The optimal VST yielded high sensitivity and few false negatives. The version of the VST tool that met this requirement had the highest probability of a correct diagnosis.

Positive and negative predictive values

Positive and negative predictive values are helpful to a clinician when considering the value of a screening tool. The positive predictive value of a measure is 'the proportion of people who test positive and in whom the disease is present' [362]. Negative predictive value is 'the proportion of people who test negative and in whom the disease is absent' [362]. Both these predictive values determine the probability that the measure will accurately diagnose the disorder [362].

Unlike sensitivity and specificity, the positive and negative predictive values are dependent on the prevalence of disease in the population that is being tested [359]. Positive and negative predictive values can only be related to the study sample or to

a sample with equal ratio of disease positive and negative people [359]. Therefore, these statistics are limited in their interpretation and in practice should be used with caution.

When applied to the current research program, a positive predictive value is the probability a positive (high) VST score correctly identifies a vestibular disorder. Negative predictive value is the probability that a negative (low) VST score excludes a vestibular disorder.

ROC curves

A ROC curve is used to determine the cut-off value that maximises the sensitivity and specificity of a test. ROC curves are an invaluable tool for finding the cut-off value that explains a 'normal' from an 'abnormal' result when the result of the screening tool is a continuously distributed measurement [363]. ROC curves are created utilising the sensitivity and specificity of the screening tool in predicting the diagnosis for each value of the screening tool. The ROC curve will determine the cut-off value that will minimise the number of false positives and false negatives. If the cut-off point is high, the screening tool is highly specific but not very sensitive and there are fewer false positives however more false negatives. Likewise, if the cut-off point is low, the test is highly sensitive but not very specific, and there are fewer false negatives but more false positives.

The AUC of a ROC curve characterises the overall accuracy of a clinical tool, with a value approaching 1.0 indicating high sensitivity and specificity [364]. The area under the diagonal line of a ROC curve is 0.5 of the total area, representing the line of zero discrimination [364]. When the test under investigation cannot distinguish between the 2 groups (disease present and disease absent), the AUC will equal 0.5, coinciding with the diagonal line. The greater the AUC, the more useful the test is in predicting the people who have the disease. A curve that falls lower than 0.5, indicates that the test is useful for predicting people who do not have the disease [364].

The choice of the cut-off point to best optimise the utility of the screening tool is recognised as requiring expert decisions by a clinician with sensitivity, specificity, and the purpose of the test taken into consideration [364]. Whilst there are several methods to determine the cut-off point for different scenarios, this is the method utilised for screening tools such as the VST. Cut-off points used for screening tools can be read from the ROC curve co-ordinates. For a screening tool, such as the VST, it is important to maximise sensitivity whilst optimising specificity [364]. This approach was adopted in determining the cut-off point on the ROC curve for the VST.

3.2.1.4 Criterion validity

Criterion validity uses a 'gold standard' test or criterion test to compare the results of the screening tool being tested [284]. This type of validity can be examined by giving both tools / tests at the same time, known as concurrent validity. To determine concurrent validity of the VST, the universally utilised DHI was accepted as the 'gold standard' test. Details of the DHI are in Section 3.5.2 of this methodology chapter.

Spearman rank order correlations

Spearman's correlation coefficient is a non-parametric statistic used when the data do not fit the assumptions for parametric data, which include normally distributed data, homogeneity of variance, interval data, and independence [364]. To say that data are interval, we must be certain that equal intervals on the scale represent equal differences in the property being measured [364]. Associations between the VST and DHI total and DHI sub-category scores were calculated using Spearman rank order correlations at initial, discharge and follow-up assessments. Given the limited range of VST scores (0-8), this conservative approach to determining concurrent validity was adopted.

3.2.2 Reliability

Reliability of a screening tool refers to 'the amount of random and systematic error inherent in any measurement' [343]. A screening tool can be considered reliable

only for a specific purpose with a specific type of subject [343]. Therefore, it is crucial to test for reliability of a tool in the context of interest. Inter-rater and intra-rater reliability, using the statistical methods of intra-class correlation coefficient (ICC) and Kappa statistic; and internal consistency of the VST, utilising Cronbach alpha are detailed in the following sections.

3.2.2.1 Inter-rater and intra-rater reliability

Rater reliability is important because it represents the degree to which the collected data accurately represents the variables measured [365]. Both inter-rater and intra-rater reliability were utilised as part of this research program. Intra-rater reliability was established to indicate how consistently a rater administered and scored the VST [343]. Inter-rater reliability was established to indicate how well two raters agreed in the way they administered and scored the screening tool [343].

An ICC assesses consistency between measures of the same class [356]. The six formulae available for calculating the ICC vary as the ICC depend on the purpose of the study, the measurements taken, and the design of the study. Intra-rater and inter-rater reliability for individual VST items and total VST scores were determined using an ICC two-way mixed, absolute agreement model [366]. Two-way mixed; absolute ICC is chosen when each rater assesses each participant [356]. 'Agreement' is chosen to give the option of determining whether the error involved in the measurement is or is not a systematic error.

The kappa statistic, is often used to test inter-rater reliability [365]. Inter-rater reliability is the 'measurement of the extent to which raters allocate the same score to the same variable' [367]. Cohen's kappa statistic was developed in 1960 to account for raters possibly guessing some variables due to doubt [367]. The kappa statistic, ranging from −1 to +1, can be interpreted as follows: 'values ≤ 0 as indicating no agreement and 0.01 – 0.20 as none to slight, 0.21 – 0.40 as fair, 0.41 – 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement' [367]. The kappa statistic can be used with small sample sizes (e.g. 5) however up to 30 or more will have greater precision [365]. Intra-rater and inter-rater agreement for individual VST items and the total VST were determined using the kappa statistic [368].

3.2.2.2 Internal consistency

Internal consistency, a type of reliability, should be considered for screening tools that are designed to test only one concept. Internal consistency is a measure of the degree to which all of the items in the screening tool address the same underlying concept [343, 346].

Cronbach alpha determined internal consistency, a form of reliability, of the VST where a score closer to 1 indicated high internal consistency. Cronbach alpha is the most common measure of scale reliability and indicated the overall reliability of the questionnaire [356]. Values of 0.8 or higher from Cronbach alpha analysis are

acceptable values for internal consistency [343]. Unidimensionality and internal consistency together support summing of the VST items for a total score.

3.2.3 Responsiveness

Responsiveness is 'the ability of an instrument to measure a meaningful or clinically important change when change has occurred' [285]. Responsiveness is important if a tool is intended to evaluate the type and amount of change in a person's behaviours or functioning over time, which is anticipated or desired, as a result of an intervention designed for that purpose [285].

Two measurements over time are required to evaluate responsiveness. It is important to know what has occurred between the measurements, to know if changes in scores are expected [284]. For the responsiveness study (see Section 4.3.3, Paper 3), a description of the intervention is detailed in the protocol. When reporting results for responsiveness testing, evidence should be provided that a proportion of the participants improved or deteriorated on the test under investigation, otherwise it is challenging to know if participants did not change or whether the screening tool was not responsive. Relevant to the determination of responsiveness, (see Section 4.3.3, Paper 3), outcomes of the VST and all measures undertaken, are reported for assessment time points (initial, discharge and three months after completion of treatment), indicating the improvement / deterioration in measurement scores across the three time points.

The literature is inconsistent in reporting the statistical methods used for calculating or determining responsiveness. Husteda and colleagues reviewed the methods for assessing responsiveness and reported two types of statistics for determining responsiveness: internal and external responsiveness [341]. Both internal and external responsiveness were determined for any changes in VST scores over time to further evaluate and validate the VST tool.

3.2.3.1 Internal responsiveness

Internal responsiveness is the ability of a tool to change over a particular pre-specified period when a known efficacious treatment is applied [341]. VPT was chosen as the known efficacious treatment to determine internal responsiveness of the VST. For people with a vestibular disorder, there is a consistent body of evidence, including a large number of randomised controlled trials that support the efficacy of VPT. Therefore, it is appropriate to test the VST for internal responsiveness following VPT. The statistics utilised for internal responsiveness include paired t-test (as reported in Paper 3, see Section 4.3.3).

Paired t-tests fall into the group of statistics most frequently used to demonstrate internal responsiveness [341]. Paired t-tests are used 'to test the hypothesis that there was no change in the average response on the tool over the two time points' [369]. This statistic is driven by the statistical significance of the observed change in the tool. Statistical significance depends on the magnitude of the change and is

reliant on an adequate sample size (n > 30) [369]. For this reason, the paired t-test was selected to determine internal responsiveness of the VST – compared to the DHI – between initial and discharge assessment and between discharge and follow-up assessment.

3.2.3.2 External responsiveness

External responsiveness 'reflects the extent to which changes in a tool relate to changes in other measures of health status' [341]. The reference measure is particularly useful when it is accepted as an indicator of meaningful and important change in the condition of the person [341]. As the DHI has been widely reported in relation to vestibular disorders [312], it was selected as the reference measure to test external responsiveness of the VST. Unlike internal responsiveness, the external responsiveness of a measure is not dependent on the treatments under investigation; therefore it has meaning in a wider range of settings [341].

To determine external responsiveness of the VST, changes in VST and DHI (total and sub-category) scores between the assessment points (initial, discharge and follow-up) were presented as mean differences and standard error of the mean differences. Correlations between the change in VST scores and the change in DHI total and sub-category scores were calculated using linear regression analysis.

Linear regression model was selected as this provides a complete inspection of the association between changes in an external standard and a screening tool under

study and can be replicated by other investigators [341]. ROC methods and correlational statistics are alternate methods for determining external responsiveness. Unlike these methods, the linear regression model does not require separate analysis to determine the degree to which change in a screening tool is associated to an external standards improvement or decline. A regression analysis 'estimates the magnitude of change in the external standard that is associated with one unit of change in the measure' [341].

The DHI was chosen as the external standard for the linear regression analysis to determine external responsiveness. The DHI is well accepted as an indication of change in people with a vestibular disorder [294, 370] and is the most widely used self-reported measurement of people with dizziness [312]. It has been translated into fourteen languages, so it is widely accepted [312].

3.2.4 Minimal clinically important difference

Minimal clinically important difference (MCID) is defined as 'the smallest difference in score in the domain of interest which people perceive as beneficial and which would mandate, in the absence of troublesome side effects and excessive cost, a change in patient management' [371]. When interpreting clinical tools it is important to understand that although small changes may be statistically significant, they may not be meaningful clinically [372, 373].

There are two types of statistical methods to determine the minimum clinical important difference, the anchor-based method and the Delphi method. The anchor-based method utilises an 'anchor' as a reference of the changes after an intervention. The Delphi method utilises a panel of experts to reach consensus of the best estimate of the MCID. For this body of research the anchor-based method was selected with the DHI selected as the comparative tool.

3.2.5 Statistics for Phase one

The rationale for the statistical analysis procedures used in Phase one have been previously detailed in Section 3.2 and are summarized in Table 3-1. The statistical analysis was conducted and completed by the PhD candidate with the guidance and assistance of Dr. Jennifer Peat, an ACU statistician employed at the candidate's institution (ACU), a J-Metric software consultant from the United States of America and both PhD supervisors.

Table 3-1 Statistics used for Phase one: Construction and validation of the Vestibular Screening Tool

Statistical method utilised	Purpose
Receiver operating characteristic curve calculated area under the curve	Comparisons in the construction and piloting of the VST (Pilot VST 1 and 2)
Cronbach alpha	Level of agreement of a panel of advanced vestibular physiotherapists in the construction and piloting of the VST VST scale reliability Internal consistency of the VST Level of agreement between assessors to

	determine content validity
Rasch model	Construct validity Unidimensionality of the VST
Factor analysis	Unidimensionality of the VST
Binary regression model	Construct validity: identify VST items to be omitted without compromising validity
Receiver operating characteristic curves calculated area under the curve, sensitivity, specificity, true / false positives and negatives, positive and negative predictive value	Discriminative capacity of the three VST versions
Spearman rank order correlations	Criterion validity, specifically concurrent validity of the VST and DHI
Intra-class correlations, 2-way mixed, absolute agreement model	Intra-rater and inter-rater reliability of the individual VST items and total VST scores
Kappa statistics	Intra-rater and inter-rater agreement for individual VST items and total VST scores
Paired t-tests	Internal responsiveness of the VST
Linear regression analysis	External responsiveness of the VST
Linear regression analysis, DHI as the reference (anchor-based method)	Minimal clinically important difference of the VST

Abbreviations: DHI, dizziness handicap inventory; VST, vestibular screening tool.

3.3 Need for further research after construction / validation of VST

In order to achieve the main aim of the thesis, to improve the service model of care (screening and management) for people presenting to hospital with a non-emergent

vestibular disorder, the first step was to construct a valid VST. The VST was designed for use with people presenting to hospital with dizziness, endeavouring to refer people with a likely vestibular disorder to a hospital-based, physiotherapy vestibular service. The second step to achieve the main aim is to establish if a physiotherapy vestibular service based in the hospital setting is effective in managing people presenting to hospital with a non-emergent vestibular disorder. Phase two set out to determine the clinical effectiveness of such a service.

It is also unknown from current literature, if people presenting to hospital with a vestibular disorder would have better clinical outcomes if physiotherapy vestibular intervention commenced in ED / AME compared to being managed in an out-patient setting after discharge from ED / AME. Therefore, Phase two also investigated any differences in clinical outcomes between an immediate intervention pathway and a delayed intervention pathway.

3.4 Phase two: Clinical effectiveness of the physiotherapy vestibular service (Research methodology underpinning Paper 4)

Phase two aimed to establish if a physiotherapy vestibular service, based in the hospital setting was clinically effective in managing people who presented to hospital with a vestibular disorder. Referrals to this physiotherapy vestibular service were based on the use of the VST in the ED / AME, to screen people presenting to hospital with non-emergent dizziness, for a likely vestibular disorder.

After screening and referral to the physiotherapy vestibular service, it was proposed that physiotherapy diagnostic assessment and management would be effective in improving people's symptoms. This hypothesis required testing and Phase two of this thesis investigated the clinical effectiveness of such a service.

It was also unknown if the physiotherapy vestibular assessment and management service should commence with people who were referred immediately, whilst in the ED / AME setting; or if a delayed, out-patient service was appropriate, after the person was discharged home from hospital. Thus, the second aim of Phase two identified any differences in clinical outcomes when an immediate versus a delayed model of care occurred.

Detail for the protocol of Phase two including research design, ethical approval, setting, participants including the inclusion and exclusion criteria, measures, validity and reliability study protocols, and statistics is detailed in Paper 4 (see Section 5.2.3).

Clinical effectiveness research should be completed with heterogeneous samples in "real-world" study sites [374], focusing on a variety of clinical and other outcomes [374]. Clinical effectiveness research is concerned with the effect of therapy on a person's symptoms, function and participation, where therapy is undertaken in normal clinical conditions. In this thesis, a pragmatic approach was adopted, with the VST score used to screen and guide referral to the vestibular rehabilitation

service. It is outside the scope of this thesis to investigate clinical efficacy, where stringent randomized controlled studies could be undertaken in the future under highly controlled conditions to test the clinical efficacy of VPT intervention of vestibular disorders in a hospital setting.

3.4.1 Analyses utilised to determine clinical effectiveness

Linear mixed models is a statistical method appropriate for testing the clinical effectiveness and was adopted for this research study. Linear mixed model analysis was also selected to compare outcomes of the two pathways of care; immediate and delayed intervention pathways.

Two statistical methods that can be used to investigate changes in outcome and trends over time, both within and between groups are: 1) linear mixed model and 2) general linear model [364]. The general linear model provides both multivariate analysis of variance and repeated measures analysis of variance (ANOVA). These statistical methods are ideal for analyzing data from cohort or experimental studies, which have a prospective or longitudinal design [364]. Both these methods can be used to analyze data from experimental studies in which outcome data from different treatment groups is collected at baseline and at ongoing time points, typically following treatment intervention [364].

Barton and Peat [364] report that in general, linear mixed models are both more theoretically correct and flexible than repeated measures ANOVA for analyzing

longitudinal data. A disadvantage of repeated measures ANOVA is that participants with missing values for any time point are omitted [364]. With linear mixed models, an advantage is that missing data points do not result in exclusion of participants from the analysis [364]. Linear mixed models are also more accommodating for study designs with unequal numbers of participants in each group [364] and when there is no requirement that each participant has the same number of repeated measures completed [364]. It is acknowledged however, that for generalization of results to a population, any missing data must be ideally 'missing completely at random'. For example, a person moves to another city or cannot attend for reasons outside their control.

Given the individualised treatment programs delivered as part of the vestibular rehabilitation, and the potential for varying number of interventions and for missing data points, linear mixed models was the form of analyses selected. The mean difference of measures across the continuum of care (initial–discharge and discharge–follow-up) for the total group was calculated and used to compare any differences in measure scores between the immediate and delayed intervention groups, at each assessment point (initial, discharge and follow-up).

3.4.2 Sample size for clinical effectiveness study

A sample size of 70 participants who continue in the study from initial assessment to discharge or from initial to follow-up would provide an 80% power to show that a

moderate within-subject effect size of 0.35 SDs at follow up is statistically significant at the P<0.05 level. In addition, a final sample size of 35 participants per group (immediate and delayed intervention groups) would provide an 80% power to show that a between-group effect size of 0.7 SDs at follow up is statistically significant at the P<0.05 level. However, the use of linear mixed models to incorporate all data over time and provide a best fit model would provide additional statistical power to show that smaller effect sizes are statistically significant.

3.4.3 Physiotherapy vestibular service

The physiotherapy vestibular service is based at a metropolitan hospital and is staffed by a senior physiotherapist with experience and training in vestibular management (completed competency-based, 5-day basic and 3-day advanced training courses). Funding for a vestibular physiotherapy position has steadily grown since 2009 to 2015 to include 1 senior fulltime physiotherapist to service the vestibular physiotherapy service within the hospital.

People who present to hospital with complaints of dizziness are screened by staff in ED (medical officers, nursing and allied health) and referred to the vestibular physiotherapist for a vestibular assessment. A referral is made either when the person scores 4 or greater on the VST, clinical signs are suggestive of vestibular pathology, differentiation is required between a peripheral vestibular cause or central pathology or vestibular management is required. A vestibular assessment is

completed by the vestibular physiotherapist either whilst the person is in ED / AME or post discharge from hospital, in the rehabilitation day therapy unit or day unit investigation therapy unit. The vestibular assessment is detailed in Section 2.6.

After completion of the vestibular assessment, the vestibular physiotherapist completes VPT as indicated (see Section 2.7). Initial assessment and management in ED / AME is in conjunction with medical officers. It is common for the vestibular assessment and the commencement of VPT to be undertaken whilst the person is in hospital, followed by further VPT post discharge from hospital. Customised VPT is offered to all people deemed to have a vestibular dysfunction. VPT includes repositioning manoeuvres for BPPV, compensatory responses (for positional or motion provoked symptoms), adaptation for visual-vestibular interaction (gaze stabilization), compensation (such as visual or somatosensory) and postural control exercises, falls prevention, (re)conditioning activities, functional / occupational retraining and psychological support (see Section 2.7). Typically, people attending the physiotherapy vestibular service require several sessions, depending on their diagnosis. Referrals to other disciplines are arranged as indicated, including ear nose throat specialist, neurologist, psychologist, audiologist, occupational therapist, medical officer.

3.5 Measures considered for Phase one and Phase two

Three types of measures were required for the validation studies of the VST and to determine the clinical effectiveness of the hospital-based vestibular physiotherapy service: vestibular diagnostic assessment measures, questionnaires related to dizziness, and balance confidence; and objective measures of balance and mobility. Vestibular assessment is an essential diagnostic component and informs the presence or absence of a vestibular disorder at each assessment time-point (admission, discharge, follow-up) as well as being used to direct efficacious treatment. Measures of balance and mobility are essential to determining the level of functional mobility impairment at the various time-points of assessment. Questionnaires form part of the vestibular assessment and have a dual purpose for this research program 1) to be utilised as the gold standard for concurrent validity and to determine external responsiveness of the VST, and 2) to inform the degree of self-reported impairment.

3.5.1 Vestibular assessment

The primary researcher of this thesis, a physiotherapist trained in VPT, completed the vestibular assessment (see Section 2.6.1), which assists in the diagnosis of a vestibular disorder. Training of the physiotherapist in VPT included completion of several courses (2-day vestibular course, 5-day competency based course in

vestibular rehabilitation, 3-day competency based advanced course, 3-day master class in vestibular rehabilitation) and 10 years clinical experience.

3.5.2 Questionnaires

Incorporation of valid and reliable self-report questionnaires is essential to assess the effectiveness of therapies [375]. The available self-report vestibular questionnaires are detailed in Chapter 2 of this thesis (see Section 2.8). In this section, justification for the selection of the two questionnaires used in this thesis, the DHI and the activities specific balance confidence short form (ABC-6), is provided.

Dizziness handicap inventory

The DHI provides a clinically useful, reliable and comprehensively validated tool that assesses the impact of dizziness on daily activities and impairment [294]. The DHI's items were constructed from interviews of patients with dizziness, referred for vestibular testing [294]. The 25 items comprise three domains: functional (9 questions, 36 points), physical (7 questions, 28 points) and emotional (9 questions, 36 points), that sum to a total score (0-100). Answers are graded 0 (no), 2 (sometimes), and 4 (Yes).

The DHI is used predominantly in people with peripheral and central vestibular pathology, but has also been used with older people [376]. People who perceive a greater impairment as a result of dizziness, have higher DHI scores and demonstrate

greater functional disorder, as measured with the dynamic gait index, than people who perceive less impairment from dizziness [370]. DHI scores above 60 indicate severe vestibular dysfunction and greater functional impairment and are related to reported falls in people with a vestibular disorder [370].

The DHI has good internal consistency for the total score (α = .89), satisfactory internal consistency for the domains (α = .72, .85); and high test-retest reliability (r = .97) [181]. Additionally, it has been shown to be sensitive to change following VPT [287] but the responsiveness of the DHI to change has only been tested on a limited number of patients, or retrospectively, preventing ultimate conclusions being drawn [335]. An 18-point difference is suggestive of a clinically important change when managing vestibular disorders [294]. There is evidence for discriminative validity between DHI scores and the number of dizziness episodes [319].

A DHI sub scale - utilising 5 items from the DHI - was found to be useful in identifying patients with BPPV [326]. The short version of the DHI however, has not been assessed for responsiveness or with other vestibular disorders. The DHI is regarded as a reference questionnaire; however, the patients who took part in the validation studies had symptoms chronic in nature and therefore are not fully representative of the population with dizziness [335].

The DHI is considered a gold standard questionnaire to measure self-perceived handicap related to dizziness [294]. It was used to determine both concurrent

validity and external responsiveness during the development phase of the VST (Phase one) as well as to determine clinical effectiveness of a physiotherapy-led hospital based vestibular service (Phase two).

Balance confidence measures

Self-perception of capability and balance confidence has been found to be more predictive of physical activity level than actual balance ability [377]. Questionnaires that quantify a person's balance confidence - the falls efficacy scale [378], falls efficacy scale – international [379], ABC [380], and ABC-6 [381] - were investigated to determine the appropriate measure for use in this thesis.

The falls efficacy scale is a valid and reliable questionnaire to measure the amount of confidence a person reports in carrying out everyday activities without falling [378]. It has good test-retest reliability, convergent and criterion validity and internal consistency [378]. A modified version of the falls efficacy scale, the falls efficacy scale – international, was developed to be suitable for a range of languages and cultural contexts and has demonstrated validity and reliability [379]. The ABC scale was a more efficient discriminator between fallers and non-fallers and yielded a wider range of responses compared to the falls efficacy scale [380]. The ABC is a 16-item tool that measures balance confidence in performing activities of daily living [380]. It has been associated with functional balance performance using the timed up and go test and dynamic gait index, duration of vestibular symptoms, general

health related quality of life [382]. The ABC is moderately negatively correlated (r = -.635) with the DHI in individuals with a vestibular disorder [383]. This tool has been found to be reliable and sensitive to changes of self-perceived balance confidence in unilateral vestibular disorders [383]. These findings support that the ABC as a valid tool for use with people with dizziness complaints and thus considered for this program of research.

The ABC-6 has been adapted for the Australian context with the six-item measure being a valid and reliable measure of balance confidence in community-dwelling older adults ($r = 0.95$; $p < 0.001$). One item in the ABC scale, that is not included in the ABC-6 scale, relates to walking on icy footpaths, a situation that is rarely encountered in Australia. This item has been replaced in the ABC-6 with reference to walking on slippery surfaces, which is more appropriate for Australia. The ABC-6 has stronger associations with falls than the ABC [381]. The ABC-6 is shorter and therefore quicker to use with people in the acute hospital setting. The 6-items are scored (0-100) with the final score converted to a percentage (0-100%). Therefore, the ABC-6 scale was used as the measure of balance confidence in this thesis.

3.5.3 Objective measures of balance and mobility

A complete assessment of a person's balance and functional mobility is essential and should include outcome measures to quantify the disorder and to monitor change with treatment. Utilising tests of balance and functional mobility performance are

helpful to explain disorder and performance impact and thus help to determine the appropriate management required. There are several documented clinical tests and measures that appear to be useful in explaining disability [313], assessing stability, mobility and risk of falling. The most clinically relevant measures for use with the person with vestibular disorder are discussed in this section to provide justification for the selected measures for this thesis. Objective measures of balance and mobility discussed include tests of postural stability, the timed up and go (TUG) test, 10 metre walk test (10MWT), Berg balance scale, dynamic gait index, and the functional gait assessment (FGA).

Timed up and go

The TUG test is used to test functional mobility and has been used to determine current falls risk by assessing gait over time [384]. The test measures (in seconds) the time it takes a person to stand-up from a standard arm chair (approximately height 46cm, arm height 65cm), walk three meters at a comfortable and safe pace, turn and walk back to the chair and sit down. The TUG assists in identifying fall risk in people with vestibular disorder [385]. Scores on the TUG greater than 11.1 seconds correlated with reports of falls in people with vestibular disorder with a sensitivity of 80% and specificity of 56% [385]. This functional outcome measure was included as a measure in this thesis as it assists in measuring risk of falls in people with vestibular dysfunction.

Ten metre walk test

The 10MWT is a measure of gait speed and step length. Regardless of diagnosis, gait speed has been found to be a strong indicator of health in people [386]. The person is asked to walk 14 metres with normal walking speed measured across the middle 10 metres. Reference data for aged matched norms is available, including for frail older adults [387, 388]. People with vestibular disorders have disordered gait [389, 390] therefore the 10MWT was included to measure gait speed.

Instability is increased in people with vestibular disorders walking with head turns [6]. The 10MWT with head turns has been used in clinical research with people with vestibular dysfunction [391]. Therefore, the 10MWT with head turns, was also included in the selection of measures for this program.

Berg balance scale

The Berg balance scale includes 14 items of sitting and standing balance with high scores predictive of falling in older adults [392, 393]. The Berg balance scale has concurrent validity with the DHI in people with vestibular disorder [394] and moderate correlation with the dynamic gait index (r = .71) [394]. However, other mobility measures – such as the dynamic gait index - appear to be more sensitive compared to the Berg balance scale, in identifying people with vestibular disorders who are at increased risk for falling [394].

Dynamic gait index

The 8-item dynamic gait index [395] has been used with older adults to determine their likelihood of falling. It has emerged as a valid indicator for quantifying gait disorder in people with vestibular disorders [69]. Lower scores (≤19 / 24) on the dynamic gait index correlated with reports of falls in people with vestibular disorder [385]. The sensitivity of the dynamic gait index at 19 or less was 70% and the specificity was 51% in predicting falls [385]. The dynamic gait index has been found to have moderate inter-rater reliability (composite K value = 0.68) [396] to excellent inter-rater reliability (r = 0.86) [375] when testing involved people with vestibular disorders. The measure also displayed a modest ceiling effect primarily with individuals with high functional levels and dizziness symptoms [397] and thus a more reliable mobility measure was sought.

Functional gait assessment

The FGA, developed for use with individuals with vestibular disorders [398], is a modification of the dynamic gait index and is a measure of community ambulation and a test of falls risk in older adults [67, 399]. The 10 item FGA uses higher-level gait tasks, designed to eliminate the ceiling effect of the dynamic gait index in individuals with a vestibular disorder [398]. The person is instructed to complete 10 gait tasks. Nine walking tasks over a 6-metre distance, require the individual to try to stay between two parallel lines, 30cm apart. The tenth task is walking up / down stairs. A score of 0-3 is given for each task and total to a score out of 30. The

scoring corresponds to severe (0), moderate disorder (1), mild disorder (2) or normal (3). Descriptive objective and subjective criteria are provided for each possible score, for each test.

The test has been demonstrated to have acceptable ($r > .7$) internal consistency, reliability, and concurrent validity with other balance measures when used with people with vestibular disorders [398]. The FGA is highly correlated with the ABC, Berg balance scale and moderately correlated with the TUG when used with older adults [399]. For older adults, FGA scores provide both discriminative and predictive validity [399]. Scores of ≤22 / 30 provide 100% sensitivity and 72% specificity to predict prospective falls, greater than the dynamic gait index, in older adults [398, 399]. As many people with vestibular disorders are older adults, the FGA is a clinically useful tool for people with vestibular disorder and assists quantifying their functional mobility problem as well as provides direction for treatment. Therefore, the FGA was chosen to test community ambulation and as a predictor of falls in this thesis.

Objective balance / stability measures

There are several measures of postural control. These include testing limits of stability (functional reach test, multi-directional reach test), static tests (Romberg, single leg stance, and tandem stance), and sensory organisation tests (modified Clinical Test of Sensory Interaction on Balance (CTSIB).

Limits of stability tests were not appropriate for inclusion in this study for several reasons. The functional reach test is predictive of fall risk in the frail elderly [400] and is a highly valid test in stroke [401]. Additionally, the functional reach in healthy adults and those with a vestibular hypofunction do not differ [402] and the multi-directional reach test [403] has not been tested in people with vestibular dysfunction.

Static tests were also not chosen for inclusion as a measure in this thesis. The Romberg test is designed to test posterior column disorders [404] and is a commonly used measure of static balance [404] however people with vestibular dysfunction may or may not have positive test results [404]. The single leg stance test is another commonly used measure of static balance, however in healthy adults aged 60-69, an age group commonly affected by vestibular disorders, the test is only able to be performed for 5 seconds [405].

The modified CTSIB assesses use of sensory information for balance [406, 407]. This test is considered the therapist's version of the laboratory Equitest, which attempts to measure the way that vision, vestibular and somatosensation interact to allow maintenance of balance against the forces of gravity. The original CTSIB test had six test conditions but the modified CTSIB (four conditions) appears to provide sufficient data to determine the treatment goals and plan. The person is instructed

to stand with their feet together, ankles touching, and stay upright in four test conditions [407]:

- Condition 1: Normal vision (eyes open) with a fixed support surface (floor)
- Condition 2: Absent vision (eyes closed), fixed support surface (floor)
- Condition 3: Normal vision (eyes open), compliant support surface (foam)
- Condition 4: Absent vision (eyes closed), compliant support surface (foam).

Each condition is timed for a maximum of 30 seconds. If the person is unsuccessful they are asked to perform up to 2 additional trials, giving a total score out of 120. The timing is stopped if the person is unable to maintain an upright position or if they open their eyes during an eyes closed condition [406].

People with vestibular disorders are impaired on the modified CTSIB compared to age matched controls [408]. The modified CTSIB has excellent test-retest reliability in older adults with 95% agreement of the total score between sessions [409]. People with vestibular dysfunction perform more poorly on condition 4 [408] - standing on foam with eyes closed. When both the visual and support-surface information are altered (condition 4), people with a vestibular disorder have difficulty staying upright. Condition 4 has also been found to be a valid, quick screening tool for detecting potential fallers in women over 40 years [410]. Therefore, condition four of the CTSIB was prioritised in the reporting of the results of this thesis.

In summary, the balance and mobility measures chosen for this research program include the TUG to inform functional mobility and falls risk, the 10MWT with and without head turns to measure gait speed, one domain related to community ambulation, and the FGA to inform functional mobility, other domains of community ambulation and falls risk; and the modified CTSIB to inform postural stability.

With the selection of measures, questionnaires and diagnostic tests in place, the effectiveness of the vestibular rehabilitation service delivered could be evaluated and reported as Phase two of this thesis. In subsequent chapters, the thesis initially reports on the outcomes related to the development and testing of the clinimetric properties of the VST and then the clinical effectiveness of the service is evaluated.

Chapter 4 Construction and validation of the Vestibular Screening Tool (Phase one)

4.1 Preamble

The systematic review (Paper 1) highlighted that there are no existing vestibular screening tools appropriate for use in the ED / AME that screen people who present to hospital with dizziness, for a vestibular disorder. The VST was constructed for use clinically in the ED / AME, with the purpose of identifying adults with likely vestibular disorders. Such a tool would have the potential to clinically streamline referrals from the acute hospital setting to hospital-based physiotherapy vestibular clinics. Results of the construction and validation process are presented in this chapter, as two papers: Paper 2 and Paper 3.

Paper 2, titled 'Construction and validation of the Vestibular Screening Tool for use in the Emergency Department and acute hospital setting' was published in Archives of Physical Medicine and Rehabilitation, in August 2015. Permission has been gained to include Paper 2 in this thesis (See Appendix D for approval letter). In Paper 2, the construct validity, content validity and discriminative validity of the VST is developed, as well as inter-rater and intra-rater reliability and internal consistency.

As presented in Paper 2, the VST may be used clinically to screen for non-emergent vestibular disorders when people present to hospital with dizziness complaints. Therefore, the VST may assist with referring appropriate people to a physiotherapy vestibular clinic for management. Vestibular physiotherapy management entails a comprehensive assessment, potential referral to other disciplines, and treatment in the form of VPT. Following intervention, a self-reported questionnaire that quickly assesses the effectiveness of vestibular interventions on the person's subjective experience (i.e. an evaluative instrument that is sensitive to changes in function after an intervention) would be particularly useful. Therefore, further testing of the VST was explored and is detailed as Paper 3.

Paper 3, titled 'Concurrent validity and responsiveness to change of the VST compared to the DHI when used with vestibular disorders' progresses the validation testing of the VST. Paper 3 investigated criterion validity (presented as concurrent validity), internal and external responsiveness of the VST, and investigated if a clinically important change could be identified for the VST. This paper is currently being reviewed for publication in the European Journal of Physical and Rehabilitation Medicine.

This chapter concludes with the quality of the clinimetric properties of the newly developed VST measured on the COSMIN checklist [282]. The COSMIN checklist was uniquely utilised in the systematic review (see Section 2.8.1) to review currently

available self-reported questionnaires' clinimetric properties. Therefore, it is also appropriate to score the newly developed and validated VST using the COSMIN checklist.

4.2 Paper 2: Construction and validation of the Vestibular Screening Tool for use in the Emergency Department and acute hospital setting[2]

4.2.1 Abstract

Aim: A new vestibular screening tool (VST) was constructed to identify likely vestibular disorders and guide referral of people with dizziness presenting to hospital. The VST was tested for construct and discriminative validity and reliability of physiotherapy assessors.

Design: Methodological study.

Setting: Emergency and acute hospital wards of a metropolitan hospital.

Participants: Adults (n = 114) presenting to hospital with dizziness (mean age = 67.36 ± 14.9 years; female = 57%).

[2] Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. *Construction and Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting.* Archives of Physical Medicine and Rehabilitation, 2015. **96**: p. 1253-1260

Outcome Measures: Three VSTs (3-item, 4-item and 5-item) were investigated. Physiotherapy vestibular diagnostic tests categorised participants as vestibular / non-vestibular. Subsets of participants were assessed twice by two physiotherapists (n = 20) and twice by the same physiotherapist (n = 30).

Results: Each of the VSTs had a good fit to the Rasch measurement model. Factor analysis demonstrated individual items loaded across 1 factor, confirming unidimensionality of the three VSTs and Cronbach alpha determined internal consistency. The 4-item VST had the greatest Area Under the Curve using receiver operating characteristic curve analysis (0.894), with highest sensitivity (83%) and specificity (84%) for identifying vestibular disorders (cut-off value ≥ 4 / 8). Sensitivity of the 3-item and 5-item versions was lower (80%). The 4-item VST scores showed very high intra-rater (Kappa item scores = .831- 1.00, ICC = 0.988) and inter-rater (Kappa item scores = .578 -.921, ICC total = 0.878) reliability.

Conclusion: The 4-item VST is a reliable, valid tool for screening people with dizziness presenting to hospital, with unidimensional construct validity, high sensitivity and specificity for identifying likely vestibular disorders. The VST could be used clinically to streamline referrals of people with dizziness to vestibular clinics.

4.2.2 Introduction

The under-diagnosis and intervention of vestibular disorders in the emergency department (ED) of tertiary hospitals is a primary concern. Dizziness is a common presentation, accounting for 4% of ED visits [13]. Small systematic studies of people in ED suggest that 24-43% of those presenting with dizziness have a vestibular disorder, such as benign paroxysmal positional vertigo (BPPV) or acute vestibular neuritis [13] but these disorders are often under-diagnosed [13]. This is concerning as these disorders have been linked with re-presentations to hospital, increased incidence of falls, fall-related injuries such as wrist and hip fractures [13, 103, 104] and increased costs.

Significant costs are associated with diagnosis of dizziness and vestibular disorders [5, 103, 104]. The challenge of interpreting clinical vestibular diagnostic bedside tests without additional training has been linked to under-diagnosis of vestibular disorders [411, 412]. For non-emergency causes, assigning effective treatment to manage dizziness has the potential to improve overall public health care costs. Vestibular physiotherapists can determine the presence of many vestibular disorders via a comprehensive vestibular assessment and provide evidence based interventions to reduce symptoms of dizziness and unsteadiness [137]. Particle repositioning manoeuvres are effective BPPV treatment [148] and vestibular rehabilitation has consistent evidence of effectiveness for vestibular disorders such

as vestibular neuritis, unilateral and bilateral vestibular hypofunction, vestibular migraine and central vestibular causes [137, 257]. Vestibular rehabilitation includes treatments such as canalith repositioning manoeuvres, as well as exercises, which facilitate vestibular adaption, habituation and / or substitution [137, 248]. In the event that clinical assessment identifies a condition not likely to respond to vestibular rehabilitation (eg. Meniere's disease), referral to appropriate specialists can be made. As vestibular physiotherapists may provide efficient and cost-effective management of many non-emergent vestibular disorders, instruments that can screen for these conditions in the ED and hospital settings are needed. Thus, screening people with dizziness in the ED setting for a vestibular disorder, but not the exclusion of central disorders, is the focus of this paper.

There are currently no validated screening tools to assist clinicians in the acute hospital setting to identify people with a likely vestibular disorder once more serious conditions have been ruled out. Head impulse, nystagmus, test of skew (HINTS) is a clinical examination that assists with diagnosis of stroke in the acute setting [123]. Once stroke and other medical emergencies have been ruled out, HINTS does not assist with further management of these people with dizziness. The dizziness handicap inventory (DHI) (25-item) evaluates dizziness impairment and vestibular dysfunction [294], the DHI subscale (5 or 2 item) aims to screen for BPPV, and the vestibular rehabilitation benefit questionnaire (22 items) has demonstrated

moderate responsiveness to vestibular rehabilitation in community contexts [296]. These questionnaires are too detailed to administer quickly in the acute hospital setting and have not been tested in the acute setting. Therefore, a short screening tool is required to identify those with a likely vestibular problem and to enable referral to vestibular physiotherapy.

This study aimed to 1) develop a new tool, vestibular screening tool (VST), for application in the acute hospital setting, to screen for non-emergent vestibular disorders when people present with dizziness and enable referral of appropriate people to vestibular physiotherapy; 2) establish construct validity of the VST; 3) determine the discriminative validity of the VST for identifying vestibular disorders; and 4) demonstrate reliability of physiotherapy assessors administering the tool.

4.2.3 Methods

Design

A methodological study was undertaken.

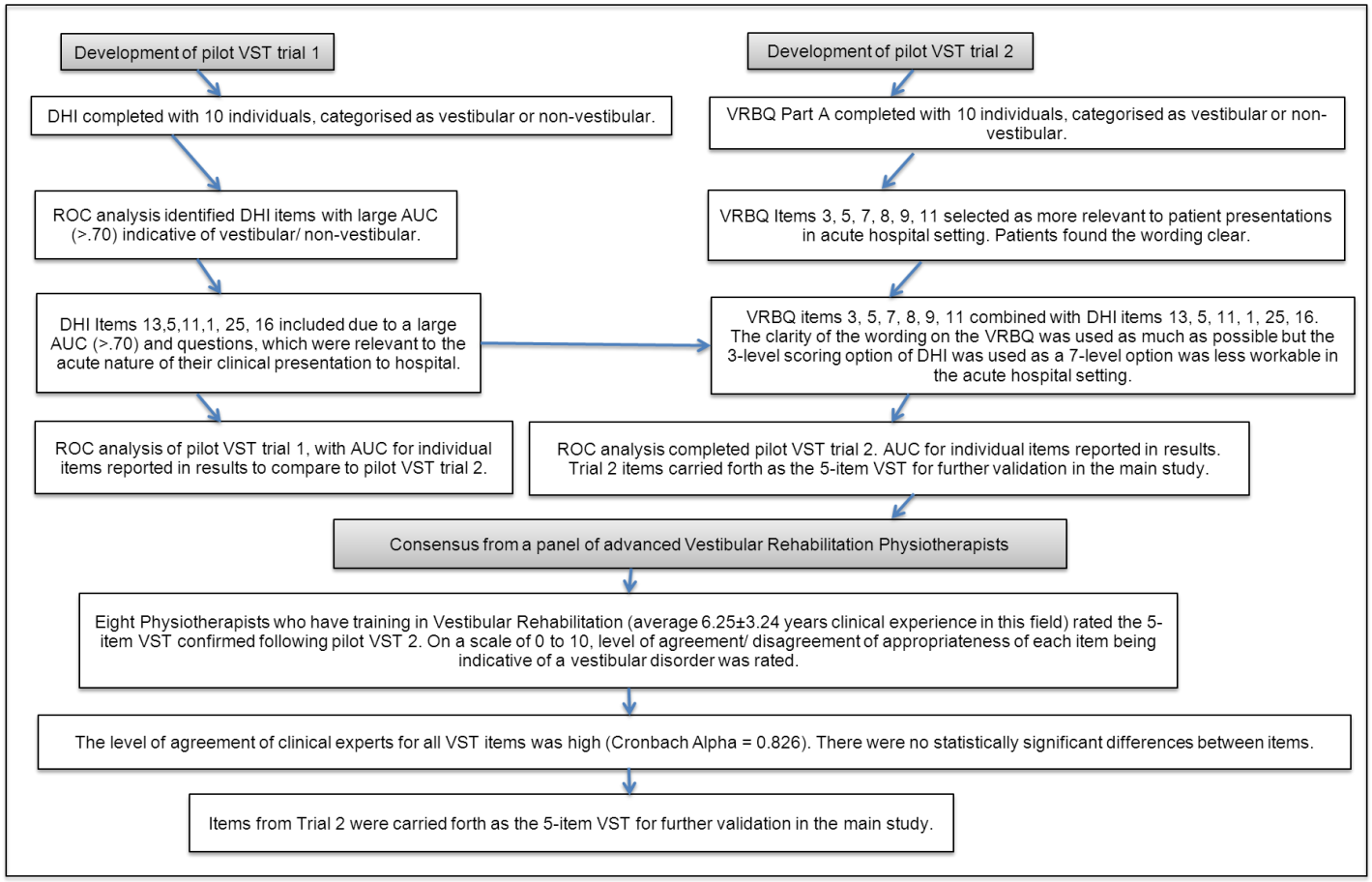
Participants and Setting

People (>18 years) complaining of dizziness who presented to ED of a metropolitan hospital were included. Following triage, dizziness was the confirmed presenting complaint. People were excluded if a known cardiac condition or stroke requiring emergency medical management was the cause to their hospital presentation, if

they were unable to provide informed consent (intoxication, mental disability, language barrier), or if recent injuries or musculoskeletal conditions limited diagnostic assessment. Participants gave written informed consent. Ethical approvals were gained by relevant institutions.

Outcome Measure: Construction and piloting the VST

The construction of the VST involved a number of steps as illustrated in Figure 4-1. A panel of experts was sought through a state-wide vestibular rehabilitation group to determine the level of agreement (0-10) about the items included in the pilot version of the 5-item VST to be assessed for validity in the main study [413].



Abbreviations: DHI, dizziness handicap inventory; ROC, receiver operating characteristic; VRBQ, vestibular rehabilitation benefit questionnaire; VST, vestibular screening tool

Figure 4-1 Construction process and piloting of Vestibular Screening Tool

Outcome measure: Main Study

The 5-item VST that was developed from the pilot trials was the primary measure under investigation (see Table 4-1) and included three possible answers as modeled on the DHI: Yes (2 points), Sometimes (1 point), or No (0 points), with a total score (0-10) recorded for each person. The item and total score were recorded.

Table 4-1 Contribution of DHI and VRBQ questions to the 5-item VST model

VST item		DHI item	VRBQ item
1	Do you have a feeling that things are spinning or moving around?		3
2	Do you feel unsteady as though you may lose your balance?	16	5
3	Does bending over or looking up at the sky make you feel dizzy?	1, 25	7, 9
4	Does lying down and / or turning over in bed make you feel dizzy?	13, 5	8
5	Does moving your head quickly from side to side make you feel dizzy?	11	11

Abbreviations: DHI, dizziness handicap inventory; VRBQ, vestibular rehabilitation benefit questionnaire; VST, vestibular screening tool.

A diagnostic vestibular assessment confirmed presence of a vestibular disorder. A comprehensive subjective examination, oculomotor examination (spontaneous nystagmus presence, smooth pursuit, gaze evoked nystagmus, saccadic eye

movements, skew deviation), vestibular ocular reflex tests (head impulse test, head shaking nystagmus), and positional testing (Hallpike-Dix test and supine roll test) were completed with use of video Frenzel equipment [143]. Demographic data recorded included gender, age and self-reported falls in past 12 months.

Protocol

a) Validation of the VST

The 5-item VST was administered verbally in ED / acute hospital settings. A vestibular diagnostic assessment was completed while participants were in hospital or within 48 hours of discharge. Participants were grouped as either 'vestibular' or 'non-vestibular' disorder. 'Vestibular' classification included one or more of the following: 1) positive Hallpike Dix (BPPV), supine roll test (BPPV), head impulse test / video head impulse test (acute vestibular neuritis, unilateral / bilateral vestibular hypofunction) [414]; 2) episodic symptoms of fluctuant hearing loss, vertigo, tinnitus or ear blockage confirmed by a specialist (Meniere's disease) [414]; 3) migraine headaches as per international headache criteria and vestibular symptoms of imbalance, vertigo, dizziness or unsteadiness (vestibular migraine) [50], direction-changing gaze-evoked nystagmus or pure down beating / upbeating / torsional nystagmus (central) [414]. A positive test needed to be consistent with presenting history and medical examination. If a positive test was inconsistent with

presenting history and medical examination, participants were categorised as 'non-vestibular'. Immediate and ongoing treatment was provided as required.

b) Reliability of Physiotherapy Assessors using the VST

Reliability was determined by examining test / re-test scores (intra-rater reliability) and consistency of scoring between assessors (inter-tester reliability). For intra-rater reliability, a convenience sample (n = 30) of participants from the main study, completed the VST twice, 20 minutes apart, before receiving treatment. For inter-rater agreement, an additional convenience sample (n = 20) from the main study, completed the VST with the primary researcher and an additional assessor (physiotherapist), 20 minutes later, whilst blinded to each other's scoring.

Data management and Statistical Analysis

Descriptive statistics of participant's demographic characteristics were reported.

Validity Analysis

Rasch and Factor analyses determined construct validity and tested the VSTs unidimensionality, respectively. Rasch analysis investigated overall fit of the VST to the Rasch scaling model by determining item-fit statistics. To evaluate item fit, infit and outfit, mean square (MnSq) and z-standardisation (zstd) statistics were calculated for each VST item. The goodness-of-fit statistics were evaluated using Wright and Linacre's criteria for rating scales [415], with values greater than 1.4

being mis-fit. Item fit reflects the extent each item contributes to the unidimensional construct of the instrument [347]. Poorly performing items would demonstrate infit and outfit (MnSq >1.4 and Zstd >2.0) [415]. Item difficulty hierarchy of VST items was generated through Rasch-Andrich rating scale model [416, 417] and is indicated in log-equivalent units (logits). Higher logit values indicate increasing item difficulty and thus are associated with higher likelihood of a vestibular disorder.

Factor analysis identified whether the VST items stem from their relationship with one (unidimensionality) or more variables. Cronbach alpha determined reliability and internal consistency of the VST where a score closer to 1 indicated high internal consistency and reliability. Unidimensionality and internal consistency supports summing of the items for a total score.

A binary regression model identified items that could be omitted from the tool. Non-significance of an item (sign > 0.05) indicates it is not a significant independent predictor of a vestibular disorder.

Discriminative capacity of the VST in identifying a vestibular disorder / non-vestibular disorder was determined using receiver operating characteristics (ROC). AUC evaluated the effectiveness and discriminative validity of each item and the VST total score to identify a vestibular / non-vestibular disorder. The greater the AUC, the better the item predicts the diagnostic category. An area of 1 indicates very high

diagnostic accuracy while an area of 0.5 indicates the item or test is no better than chance in classifying people.

Non-significant items in the binary regression model and items with the lowest AUC (ROC analyses) were removed from the VST. This resulted in three potential VSTs (5-item, 4-item and 3-item VST), which were then compared, to determine the best VST construct.

Sensitivity and specificity of each VST was calculated to determine the optimal cutoff score for the VST to correctly discriminate between a vestibular / non-vestibular disorder. The optimal VST would yield high sensitivity and few false negatives. The version of the VST tool that met this requirement had the highest probability of a correct diagnosis. Positive predictive value is the probability a positive (high) VST score correctly identifies a vestibular disorder. Negative predictive value is the probability that a negative (low) VST score excludes a vestibular disorder. Data analyses used SPSS (Version 22) and JMetrik version 3.1 for Rasch analysis.

Reliability Analysis

Intra-rater and inter-rater reliability for individual VST items and total VST scores were determined using intraclass correlation coefficient (ICC) two-way mixed,

absolute agreement model [366]. Intra and inter-rater agreement for individual VST items and the total VST were determined using the Kappa statistic [368].

4.2.4 Results

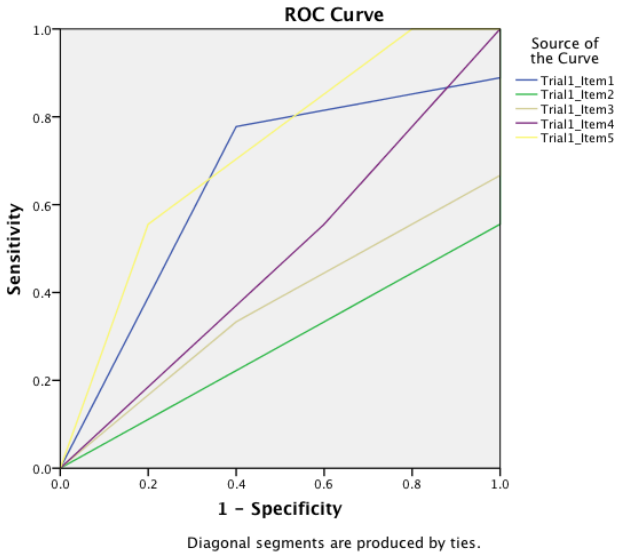
Pilot Study: VST (Trials 1 and 2)

Data (gathered March-May, 2013) from two sets of 10 people participating in pilot trials showed no significant difference between the convenience samples: VST trial 1 participants were aged 74.79 (64% female) and VST trial 2 participants were aged 74.58 (58% female).

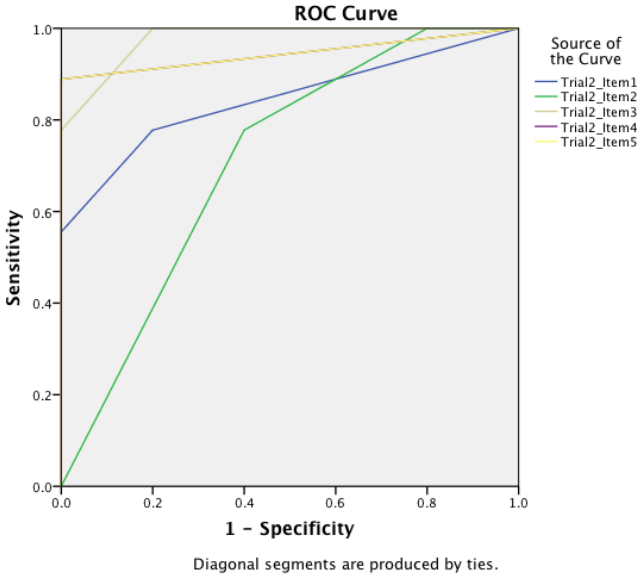
Figure 4-2 shows the AUC for each item of both pilot tools. The AUC for items in VST-trial 2 was higher. It was also noted that the wording of items from VST-trial 1 was less specific to the presenting condition of acute dizziness. These data confirmed that the items in VST-trial 2 more appropriately informed the 5-item VST for the main study.

Main Study

One hundred and fourteen subjects (demographics and characteristics in Table 4-2) who presented to hospital with dizziness (July 2013 -June 2014) were enrolled in validation studies of the VST.



A. Receiver operating characteristic curve for Pilot vestibular screening tool trial 1



B. Receiver operating characteristic curve for Pilot Vestibular Screening Tool trial 2

Figure 4-2 Comparison of area under the curve for pilot vestibular screening tool

Thirty-three participants (29%) were assessed within two days of presenting to ED whilst 81 (71%) were assessed on the same day as their hospital presentation. No significant differences ($p > 0.05$) in characteristics between groups were found.

Table 4-2 Demographics and clinical characteristics of participants (n = 114)

Characteristic	Values
Mean age ± SD (y)	67.36 ± 14.88
Female, n (%)	65 (57)
Self-reported falls in past 12 months, n (%)	34 (30.9)
Clinical Diagnosis:	
Vestibular diagnosis, n (%) • BPPV (n = 46) • Acute vestibular neuritis (n = 17) • Unilateral vestibular hypofunction (n = 9) • Vestibular migraine (n = 5) • Bilateral vestibular hypofunction (n = 3) • Meniere's disease (n = 3) • Central (n = 3)	86 (75.4)
Non-vestibular diagnosis, n (%)	25 (21.9)
Unspecified Diagnosis, n (%)	3 (2.6)

Abbreviations: BPPV, benign paroxysmal positional vertigo

Validation

Table 4-3 summarises results from the Rasch analysis. All infit and outfit statistics were good, indicating each VST item was a good fit to the Rasch measurement

model. The item difficulty hierarchy indicates the most difficult items were item 1, followed by item 4. The least difficult item was item 2. VST item score to Rasch measure conversion is detailed in Table 4-4.

Table 4-3 Rasch analysis (rating scale model) of the 3-item, 4-Item and 5-item VST

	VST Item	Difficulty (logits)	Std Error	Infit MnSq	Infit ZStd	Outfit MnSq	Outfit ZStd
5-item VST	1	0.38	0.17	1.01	0.09	1.01	0.15
	2	-0.55	0.18	0.88	-0.85	0.86	-0.76
	3	0.32	0.18	0.83	-1.23	0.76	-1.51
	4	0.38	0.17	1.09	0.66	1.02	0.16
	5	0.12	0.17	1.17	1.25	1.10	0.70
4-item VST	1	0.23	0.17	1.10	0.27	1.06	0.43
	3	-0.45	0.18	0.86	-0.97	0.80	-1.15
	4	0.23	0.17	1.01	0.08	0.94	-0.31
	5	-0.02	0.17	1.09	0.68	1.01	0.13
3-item VST	1	0.08	0.18	0.96	-0.29	0.98	-0.10
	4	0.08	0.18	0.94	-0.42	0.91	-0.60
	5	-0.16	0.18	1.10	0.73	1.03	0.27

Abbreviations: MnSq, mean square; Std Error, standard error; VST, vestibular screening tool; Zstd, z-standardised

Table 4-4 VST item score to Rasch measure conversion

	5-item VST			4-item VST			3-item VST	
Score	VST Rasch-derived	Std Err	Score	VST Rasch-derived	Std Err	Score	VST Rasch-derived	Std Err
0	2.8	1.84	0	1.7	1.84	0	.60	1.85
1	4.1	1.04	1	3.0	1.04	1	1.90	1.06
2	4.8	0.77	2	3.7	0.78	2	2.80	0.83
3	5.4	0.67	3	4.3	0.70	3	3.40	0.78
4	5.8	0.63	4	4.7	0.67	4	4.00	0.83
5	6.2	0.62	5	5.2	0.70	5	4.90	1.06
6	6.6	0.63	6	5.7	0.78	6	6.10	1.85
7	7.0	0.67	7	6.5	1.04			
8	7.5	0.77	8	7.8	1.84			
9	8.3	1.04						
10	9.5	1.84						

Abbreviations: Std Error, standard error; VST, vestibular screening tool

Principal components factor analysis [418] demonstrated that the individual VST items loaded across 1 factor, confirming unidimensionality of the tool. The Cronbach alpha value was .81 for the cohort, indicating high internal consistency of VST items. The support for unidimensionality and internal consistency of the items

scoring allow the total raw VST item scores to be added to determine a VST total score.

The binary regression model showed that item 2 (sign = .802) and item 3 (sign = .265) are not significant independent predictors of a participant having a vestibular disorder. The AUC for items 1 to 5 respectively (.784, .663, .771, .887, .819), demonstrated that item 2 had the lowest AUC, followed by item 3, supporting the finding that item 2 and 3 may be able to be omitted from the VST total.

Three versions of the VST totals (3-item, 4-item and 5-item) were compared for discriminative capacity in identifying a vestibular disorder or a non-vestibular disorder (Table 4-5). The 5-item VST included items 1-5; the 4-item VST included items 1, 3, 4 and 5 (omitting item 2); while the 3-item VST did not include items 2 and 3, leaving items 1, 4 and 5. The 4-Item VST showed the greatest AUC (.894), indicating that this version correctly classified participants as either vestibular or non-vestibular based on a physiotherapy vestibular diagnostic assessment 89.4% of the time.

The optimum validity indexes of sensitivity and specificity reveal the cut-off score indicating an increased likelihood of a vestibular disorder (Table 4-5). Each VST version (3-item, 4-item and 5-item) had a specificity of 84%. The 4-item VST had a slightly higher sensitivity of 82.6% at a cut-off value of ≥4 / 8, than the other versions.

Table 4-5 compares raw total VST scores for the three versions of the tool with Rasch measure converted scores. There was no difference between raw and Rasch converted scores indicating that the scoring system using raw scores is appropriate.

When item 2 was removed from the total score (4-item VST), the R square value (.533) did not change indicating item 2 did not explain any additional variation in the outcome. When item 3 was also removed (3-item VST), the reduction in R square values of the model (.522) indicated that item 3 was explaining some variation in the outcome.

Diagnoses of participants with false negative results included BPPV (6), vestibular neuritis (2), unilateral vestibular hypofunction (3), Meniere's Disease (1) and unspecified (3).

Table 4-5 VST totalled scores and Rasch converted scores for ROC analysis, discriminative Capacity

	5-item VST Raw Scores	5-item Rasch Converted	4-item VST Raw Scores	4-item VST Rasch Converted	3-item VST Raw Scores	3-item VST Rasch Converted
Area Under the Curve	.885	.885	.884	.884	.890	.890
VST score that indicates increased likelihood of vestibular disorder	≥5 / 10	≥6 / 9.5	≥4 / 8	≥4.5 / 7.8	≥3 / 6	≥3.1 / 6.1
Sensitivity (%)	80.2%	80.2%	82.6%	82.6%	80.2%	80.2%
Specificity (%)	84.0%	84.0%	84.0%	84.0%	84.0%	84.0%
True Positive	69	69	71	71	69	69
True Negative	21	21	21	21	21	21
False Positive	4	4	4	4	4	4
False Negative	17	17	15	15	17	17
Positive Predictive Value	94.5%	94.5%	94.7%	94.7%	94.5%	94.5%
Negative Predictive Value	55.3%	55.3%	58.3%	58.3%	55.26%	55.26%

Abbreviations: VST, vestibular screening tool

Reliability

Table 4-6 shows that the intra-rater and inter-rater reliability was very high for the three versions of the VST. Intra-rater reliability was very high for each item and inter-rater reliability was very high for items 1-3 and moderately high for items 4 and 5.

Table 4-6 Intra-rater and inter-rater reliability for individual items and total scores for the Vestibular Screening Tool (5-item, 4-item and 3-item VST Versions)

	Item 1	Item 2	Item 3	Item 4	Item 5	5-item VST	4-item VST	3-item VST
	Kappa					ICC (3,2)		
Intra-rater reliability (n=30)	.848	.907	1.00	.831	.923	.993	.994	.990
Inter-rater reliability (n=20)	.921	.829	.827	.599	.578	.954	.938	.904

Abbreviations: VST, vestibular screening tool

4.2.5 Discussion

This study is novel, providing evidence of the construction, validity and reliability of a new tool, the Vestibular Screening Tool, for use with people presenting to emergency and acute hospital settings with dizziness for whom emergent conditions have been ruled out. The VST was shown to be a unidimensional tool with strong construct validity. All versions of the VST (5-item, 4-item and 3-item) were found to have an overall fit to the Rasch rating scale model with each version

demonstrating high sensitivity, specificity and discriminative validity in identifying presence / absence of a vestibular disorder.

The 4-item VST demonstrated marginally higher AUC, sensitivity and negative predictive value compared to the 5-item and 3-item VST. Item 2 - 'Do you feel unsteady, as though you may lose your balance?' - was less discriminative of a vestibular disorder than the other items. Item 2 was selected in the construction phase due to its potential relevance to vestibular disorders [103]. When the binary regression model and ROC analyses were considered, item 2 was not as discriminative, therefore the 4-item VST was considered superior. When item 2 was removed from the tool (4-item VST), a marginal improvement in sensitivity of the tool occurred. As item 2 is non-specific to a vestibular disorder, it was not surprising that it did not contribute to the same degree as the other items to the VST's discriminative capacity. Thus, the 4-item VST demonstrated marginally better discriminative validity in identifying people likely to have a vestibular impairment.

The construct validity allows the individual who uses the VST to be confident in summing the individual VST items to a total VST score. Use of Rasch analyses (converted scores) is a strength of the study, offering advanced research application that confirms use of the VST Scores (whole numbers) and enables the clinician to readily apply the tool and sum the scores when used in a busy hospital setting. The

extensive analyses undertaken supports clinical and research use of the VST to screen people with dizziness for vestibular disorders in the acute hospital setting.

Other developed questionnaires frequently used with vestibular populations have not undergone all components of validation, which have been applied to the VST. The DHI development included internal consistency, test re-test reliability and content validity [294] whereas the vestibular rehabilitation benefit questionnaire (VRBQ) included test re-test reliability, internal consistency and responsiveness to change [296, 419]. Several other outcome measures have undergone components of the validation techniques utilised in this study. For example, construct validity using Rasch analysis was determined for the Dynamic Gait Index [69] and, discriminative and predictive validity was undertaken with the Functional Gait Assessment [399]. Thus, the extensive analyses undertaken with the VST, confirms the strength of the analysis of this tool.

It is recommended that the 4-item VST (see Figure 4-3) be utilised clinically in the acute hospital setting, along with clinical opinion. The 4-item VST is scored out of 8, with a cut-off score of ≥4 / 8 indicative of the likely presence of a vestibular disorder. This signifies the need to refer to vestibular physiotherapy. The false negatives are those who scored low VST scores (< 4 / 8) but were identified to have a vestibular disorder. People with vestibular conditions may still be missed with the VST. The VST is better at ruling in non-emergent vestibular issues than ruling them

out. Therefore, clinical opinion should be utilised in conjunction with the VST score. As the positive predictive value of the VST is 89%, few over-referrals for physiotherapy services of this group are likely to occur. Being reviewed by a physiotherapist also provides an opportunity to appropriately refer to audiologists, psychologists and specialists as required. When used in the acute hospital context, the VST may indicate if a person is likely to have a vestibular disorder, enabling people to be appropriately referred, reviewed and managed. Further research could be undertaken to determine the responsiveness of the VST pre and post vestibular rehabilitation treatment and the outcome of individuals with false negatives.

Vestibular Screening Tool (VST)	Yes (2)	Some-times (1)	No (0)
1. Do you have a feeling that things are spinning or moving around?			
2. Does bending over and / or looking up at the sky make you feel dizzy?			
3. Does lying down and / or turning over in bed make you feel dizzy?			
4. Does moving your head quickly from side to side make you feel dizzy?			
TOTAL	/ 8		

Figure 4-3 4-item vestibular screening tool

Study limitations

The diagnostic categorisation was completed by an experienced vestibular physiotherapist using video Frenzel equipment, in agreement with the treating medical officer. However, an ear nose throat specialist or neurologist did not routinely assess participants, nor were laboratory tests utilized. The VST does not attempt to exclude a central disorder such as stroke, nor discriminate between central and peripheral vestibular disorders. The VST was tested with physiotherapists only. As test-retest reliability was performed with a relatively short interval between assessments, reliability results may be skewed. Further testing involving the VST as a screening tool, could involve medical officers, other health professionals or other hospital departments and community settings.

4.2.6 Conclusion

The 4-item VST is a reliable and valid tool for use in the acute hospital setting (83% sensitivity and 84% specificity) to screen for non-emergent vestibular disorders when people with dizziness present to hospital.

Linking Paper 2 and Paper 3

The VST may assist with referring appropriate people to a physiotherapy vestibular clinic for management. Further testing of the VST was explored and is detailed as Paper 3.

4.3 Paper 3: Concurrent validity and responsiveness to change of the VST[3]

4.3.1 Abstract

Background: Vestibular disorders are common in the Emergency Department and valid tools are required to screen for vestibular disorders and monitor outcomes.

Aim: Determine the new vestibular screening tool's (VST) concurrent validity with the dizziness handicap inventory (DHI), responsiveness to change in symptoms after vestibular rehabilitation across the continuum of care and the minimal clinically important difference.

Method: Longitudinal prospective study undertaken with adults (n = 195) presenting to hospital with non-emergent dizziness (mean age = 64.4 ± 15.4 years; female = 59.5%). The VST and DHI were completed concurrently at three assessment points: initial, discharge and 3-month follow-up. Physiotherapy tests categorised people (vestibular / non-vestibular). People in the vestibular group were offered treatment.

[3] Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. Concurrent validity and responsiveness to change of the Vestibular Screening Tool, to screen for vestibular disorders in the acute hospital setting. Otorinolaringologia, 2018. Manuscript in press.

Results: The VST demonstrated moderate to high associations with DHI total (r = .673 - .768) and with DHI physical sub-category scores (r = .759 - .809) at each assessment-point. The mean change scores for both measures significantly decreased across the continuum of care ($p \leq 0.05$) with a clinically meaningful VST change score of 2-points determined. Across the care pathway, moderate to high associations presented between changes in VST and DHI total scores (r = .697-.709).

Conclusion: The VST demonstrates concurrent validity with the DHI and is responsive to change following vestibular rehabilitation intervention. The VST could be clinically useful in a hospital setting.

4.3.2 Introduction

Vestibular disorders are common clinical manifestations in the emergency department (ED) [3]. Vestibular disorders have been reported as high as 45% as an underlying cause of people complaining of dizziness [4]. Individuals with dizziness are frequently being referred to physiotherapy for assessment and treatment. Valid and reliable tools are required for use in busy, acute hospital settings to screen for vestibular disorders and monitor physiotherapy clinical outcomes post treatment.

It is useful to work with screening tools that are indicative of vestibular dysfunction, and enable a person's responsiveness to treatment to be recorded [287]. Clinical tools need to be easy to use, quick to administer when assessing the nature of self-reported dizziness symptomology, and validated for use in the acute hospital

setting. A tool would be particularly useful if it demonstrated responsiveness to interventions, allowing documentation of change in a persons' subjective impairment as they respond to treatment.

A new tool, the vestibular screening tool (VST) has been shown to be a valid and reliable tool to screen for non-emergent vestibular disorders when people with dizziness present to ED or acute hospital settings [420]. The VST is a unidimensional tool with strong construct validity, high inter-rater and intra-rater reliability, and discriminative validity for identifying vestibular disorders for use in the acute hospital setting [420]. The 4-item VST is scored out of eight (8) with the cut-off score (≥ 4 / 8) indicative of the likely presence of vestibular dysfunction. However, investigations of concurrent validity, responsiveness to change, and minimal clinically important difference (MCID) of the VST have not been established.

Concurrent validity of the VST with self-report instruments related to dizziness impairment and impact on daily activities and participation, such as the dizziness handicap inventory (DHI) is worthy of investigating to further validate the VST. Concurrent validity can be defined as using a criterion test to compare the results of the outcome measure being tested [284], where both outcome measures are examined at the same time. The DHI provides information about self-perceived dizziness impairment, and due to widespread use and documented reliability and

validity, it is commonly selected to report outcomes of vestibular physiotherapy (VPT). Therefore, to determine concurrent validity of the VST, the widely used DHI was used as the criterion test.

The VST's responsiveness to change has also not been investigated. Responsiveness is the ability of an instrument to measure a meaningful or clinically important change when change has occurred [285]. Two types of responsiveness to change are internal and external [341]. Internal responsiveness characterises the ability of a measure to change over a particular pre-specified period when a known efficacious treatment can be applied [420]. VPT was chosen as the known efficacious treatment to determine internal responsiveness of the VST. For people with a vestibular disorder, there is a consistent body of evidence, including a large number of randomised controlled trials that support the efficacy of VPT [137, 230, 248, 257]. Therefore, it is hypothesised that VST scores will decrease after VPT intervention, informing internal responsiveness.

External responsiveness reflects the extent to which changes in a measure over a specified time frame relate to corresponding changes in a reference measure of health status [341]. The reference measure is particularly useful when it is accepted as an indicator of meaningful and important change in the condition of a person [341]. Therefore, the DHI was selected as the reference measure to test external responsiveness of the VST. Unlike internal responsiveness, the external

responsiveness of a measure is not dependent on the treatments under investigation; thus having meaning, in a wider range of settings [341]. It is hypothesised that VST scores will decrease as DHI scores decrease with moderate to high associations determined.

Data from this study will allow us to demonstrate the MCID for the VST. MCID (as defined in Section 3.2.4) is important as although small changes in clinical measures may be statistically significant, they may not be meaningful clinically [372, 373].

If concurrent validity of the VST with the DHI, and responsiveness to change after VPT intervention is established with people presenting with non-emergent vestibular dysfunction to the hospital setting, the value of using the VST as a quick measure of subjective dizziness impairment and response to treatment would be strengthened. Thus, this study aimed to: 1) establish concurrent validity of the VST by testing the association with the DHI (total and sub-categories) in people with dizziness referred directly from the ED / acute hospital setting to the vestibular service, at initial, discharge and follow-up assessment; 2) determine the internal and external responsiveness of the VST, and 3) investigate if a MCID could be identified for the VST.

4.3.3 Methods

Design

A longitudinal, observational prospective study was undertaken.

Participants and Setting

People (>18 years) complaining of dizziness who presented to ED of a metropolitan hospital were included. Following triage, dizziness was the confirmed presenting complaint as documented by the triage team in ED. People were excluded: if a known cardiac condition or stroke requiring emergency medical management was the cause of their hospital presentation; inability to provide informed consent (intoxication, mental disability, language barrier); or if injuries or musculoskeletal conditions limited diagnostic assessment. Informed written consent was gained with participants. Ethical approvals were gained by the relevant institutions.

Outcome Measures

Primary measures included the VST [420] and the DHI [294]. The VST items were scored (0-8) with a higher score indicative of a vestibular disorder [420]. The DHI is a 25-item questionnaire (0-100) split into three categories: functional, physical and emotional. It is used to evaluate dizziness impairment and vestibular dysfunction and indicates the effect of symptoms on participation and quality of life [287, 294]. Higher scores are indicative of greater vestibular dysfunction [370]. The DHI is sensitive to change after VPT for those with primary vestibular deficits [137, 269].

Protocol and intervention

The VST and DHI were completed concurrently with participants on presentation to hospital or during the initial physiotherapy vestibular assessment. Initial

assessments were completed with participants whilst in hospital or in the out-patient vestibular service after discharge from hospital. The VST was administered verbally and the DHI either verbally or completed independently. Assistance was offered if the participant had difficulty completing the questionnaires.

A vestibular diagnosis was made when a positive clinical test was consistent with presenting history and the medical officer's opinion. A diagnostic vestibular assessment confirmed a vestibular disorder and included: comprehensive subjective examination, oculomotor examination (spontaneous nystagmus presence, smooth pursuit, gaze evoked nystagmus, saccadic eye movements, skew deviation), vestibular ocular reflex tests (head impulse test, head shaking nystagmus), and positional testing (HPD test and head roll test) completed with video Frenzel equipment [143]. Table 4-7 summarises the vestibular disorders identified along with the relevant diagnostic tests used in the assessment.

Participants that did not fit these criteria were categorised as 'non-vestibular. If it was unclear if symptoms were from a vestibular origin or not, an 'unspecified' diagnosis was given and participants were referred for ongoing specialist assessment (audiology / ear nose throat / neurology). Demographic data recorded included gender, age, and self-reported falls in the past 12 months.

Table 4-7 Use of clinical assessment tests to inform vestibular diagnostic categorisation.

Diagnostic groups	Tests
Benign paroxysmal positional vertigo	Positive Hallpike Dix / supine head roll test [148]
Acute vestibular neuritis, unilateral / bilateral vestibular hypofunction	Positive head impulse test / video head impulse test consistent with history or positive caloric result [173]
Meniere's disease	Episodic symptoms of fluctuant hearing loss, vertigo, tinnitus or blockage of the ear confirmed by a specialist [117]
Vestibular migraine	Migraine headaches as per international headache criteria and vestibular symptoms of imbalance, vertigo, dizziness or unsteadiness [115]
Central vestibular	Head impulse, nystagmus, test of skew (HINTS) in context of acute vestibular syndrome [123]; or pure down-beating / up-beating / torsional nystagmus, with vestibular symptoms diagnosed as central by a specialist.
Unspecified vestibular	Vestibular symptoms including vertigo requiring further specialist assessment
Motion sensitivity	Moderate to severe score on the motion sensitivity quotient without other diagnosis [421]

Customised VPT was offered to all people deemed to have a vestibular dysfunction. Efficacious management included repositioning manoeuvres for benign paroxysmal positional vertigo (BPPV), compensatory responses (for positional or motion provoked symptoms), adaptation for visual-vestibular interaction (gaze

stabilisation), compensation (such as visual or somatosensory) and postural control exercises, falls prevention, (re)conditioning activities, functional / occupational retraining and psychological support as required [137]. A discharge assessment was completed on the final day of treatment and a follow-up assessment was undertaken three-months after discharge from VPT. The VST and DHI were repeated concurrently as part of the discharge and follow-up assessments.

Concurrent validity analysis

Associations between the VST and DHI total and sub-category scores were calculated using Spearman rank order correlations at initial, discharge and follow-up assessments. Given the limited range in VST scoring (0-8), a conservative approach to determining concurrent validity was adopted. Correlation coefficient values were classified as follows: 0.40-0.70: moderate correlation, and 0.75-1.00: high correlation [422].

Internal responsiveness analysis

Means, SD and ranges of scores of the VST, DHI and DHI sub-categories completed at initial, discharge and follow-up assessment were reported. Paired t-tests were completed between initial and discharge VST scores, discharge and follow-up VST scores and initial and follow-up VST scores to determine if a statistically significant change in the VST occurred (and was maintained) after VPT. Paired t-tests are most

frequently used to demonstrate internal responsiveness [341]. Significance level was set at $p < 0.05$.

External responsiveness analysis

To determine external responsiveness of the VST, the changes in VST and DHI (total and sub-category) scores between the assessment points (initial, discharge and follow-up) were presented as mean differences, SE of the mean differences. Correlations between the change in VST scores and the change in DHI total and sub-category scores were calculated using linear regression analysis. Linear regression analyses were completed for changes in VST and changes in DHI scores from initial to discharge assessments and between discharge and follow-up assessments to determine the degree one measure changed compared to the other at different time points [341].

Minimal clinically important difference analysis

The anchor-based method was used, which compares a person's change score with another measure of clinically relevant change [372, 423]. Linear regression analysis showed the degree to which the VST score changed compared to the DHI to determine the MCID of the VST [371, 424]. Significance level was set at $p < 0.05$. Data were analysed using the SPSS statistical package (Version 22).

4.3.4 Results

One-hundred and ninety-five subjects who presented to hospital with dizziness (July 2013 – April 2015) were enrolled in this study (demographics and characteristics in Table 4-8).

One-hundred and sixty-six participants (86.13%) completed the VST and DHI concurrently whilst they were in hospital. Another 29 participants (14.87%) completed the questionnaires concurrently after being discharged from hospital. These participants were included to assist with determining concurrent validity and responsiveness of the VST for people who presented to hospital with symptoms of dizziness. Initial diagnostic assessment was completed either whilst in hospital (n = 112, 57.44%) or within an average of 22.04 days (3-77 days) of presenting to hospital (n = 83, 42.56%).

Table 4-8 Demographics and clinical characteristics of participants

Demographic characteristic	Total Group (N = 195)
Mean age (SD, range) (y)	64.43 (15.36, 19.13 – 94.96)
Female, n (%)	116 (59.5%)
Self-reported falls in past 12 months, n (%)	57 / 189 (29.2%)
Independent gait (no supervision indoors), n (%)	152 / 179 (77.9%)
Vestibular: n (%)	
• BPPV	78 (40.0%)
• Vestibular neuritis	27 (13.9)
• Unilateral vestibular hypofunction	13 (6.7)
• Bilateral vestibular hypofunction	3 (1.5%)
• Vestibular migraine	7 (3.6%)
• Meniere's disease	3 (1.5%)
• Central	4 (2.1%)
• Motion sensitivity	5 (2.6%)
• Unspecified vestibular	11 (5.6%)
Non-vestibular, n (%)	42 (21.0)
Unspecified, n (%)	2 (1.0%)
Self-reported dizziness for total group: initial assessment mean (SD, range):	
• VST	4.72 (2.65, 0-8)
• DHI	44.90 (28.50, 0-100)
• DHI physical sub-category	14.52 (8.98, 0-28)
• DHI functional sub-category	17.45 (11.25, 0-36)
• DHI emotional sub-category	12.93 (10.51, 0-36)

Abbreviations: BPPV, benign paroxysmal positional vertigo; DHI, dizziness handicap inventory; VST, vestibular screening tool

Concurrent validity of VST and DHI

Table 4-9 reports the moderate to high associations between the VST scores and DHI total and sub-category scores completed at initial, discharge and follow-up assessment for the total group.

Table 4-9 Association of the VST with the DHI, a measure of dizziness impairment, at three assessment time-points for the total group.

	Initial VST	Discharge VST	Follow-up VST
DHI total	.768**	.673**	.744**
DHI physical	.809**	.759**	.808**
DHI functional	.714**	.504**	.736**
DHI emotional	.632**	.415**	.621**

Abbreviations: DHI, dizziness handicap inventory. ** ≤ 0.001

Data from the vestibular diagnostic group showed that the associations between the VST and the DHI scores were similar to those yielded by the total group ($p \leq 0.05$).

Two participants with vestibular migraine had BPPV and four participants with vestibular neuritis developed BPPV across the treatment period. Of the vestibular group (n = 151), 106 (70.0%) completed a discharge assessment and 85 (80.2%) of those who completed a discharge assessment also completed a three-month follow-up assessment. Subjects who did not complete a discharge assessment, either reported resolution of symptoms or did not wish to return for ongoing treatment.

Internal responsiveness results

Table 4-10 displays VST and DHI (and sub-category) scores following VPT and at follow-up for the vestibular diagnostic group. The mean change scores for VST and DHI (and sub-category) scores following VSP between initial to discharge, discharge to follow-up and initial to follow-up are reported in Table 4-11.

Table 4-10 Means, SD and ranges of VST, DHI (and sub-category) scores for the vestibular diagnostic group on initial assessment and after VPT intervention at discharge and follow-up assessments.

Measures	Initial (n = 138)			Discharge (n = 94)			Follow-up (n = 81)		
	Mean	SD	range	Mean	SD	range	Mean	SD	range
VST (/ 8)	5.90	2.17	0-8	1.15	1.61	0 - 8	1.56	2.01	0 - 7
DHI total (/ 100)	51.50	26.97	0-100	13.22	16.55	0 - 66	14.78	21.59	0 - 78
DHI physical (/ 28)	16.60	8.53	0-28	4.28	5.55	0 - 24	5.26	7.24	0 - 28
DHI functional (/ 36)	19.87	10.70	0-36	4.79	6.59	0 - 26	5.48	8.59	0 - 30
DHI emotional (/ 36)	15.03	10.34	0-36	4.20	6.43	0 - 26	4.37	7.09	0 - 28

Abbreviations: DHI, dizziness handicap inventory; VST, vestibular screening tool

Table 4-11 Mean difference scores (SD, number of participants) for VST and DHI (sub-categories) assessment time-points for individuals with a vestibular disorder.

Measures	Initial - Discharge			Discharge – Follow-up			Initial - Follow-up		
	Mean difference	SD	n	Mean difference	SD	n	Mean difference	SD	n
VST (/ 8)	4.45	2.63	95	-0.59	2.28	59	3.16	2.92	87
DHI total (/100)	41.53	27.56	85	-4.45	22.10	56	31.59	32.96	95
DHI physical (/28)	13.07	9.33	85	-2.07	6.76	55	9.32	10.32	93
DHI functional (/36)	16.12	10.12	85	-2.04	9.64	55	12.71	12.84	93
DHI emotional (/36)	12.34	10.72	85	-0.78	7.82	55	9.40	11.24	93

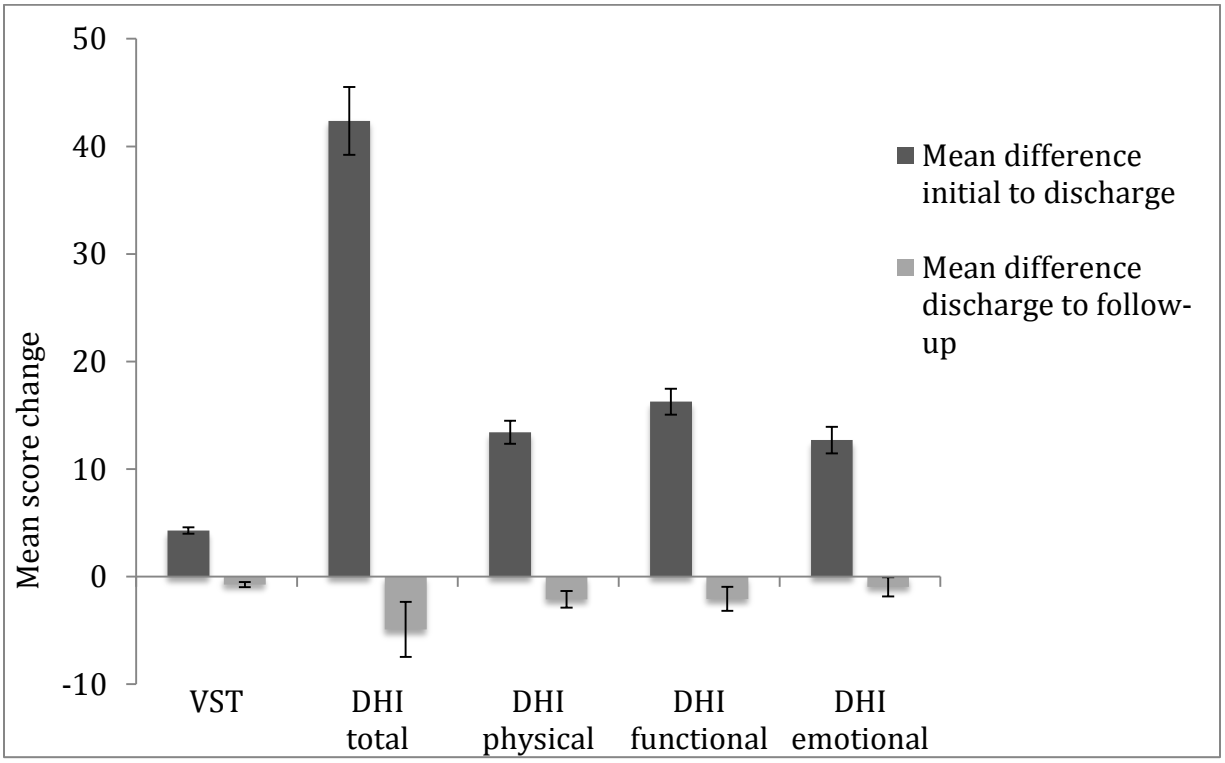
Abbreviations: DHI, dizziness handicap inventory; VST, vestibular screening tool

VST and DHI scores significantly reduced between pre and post VPT intervention in individuals who presented to hospital with a vestibular disorder ($p = 0.000$), and remained significantly lower three months after completion of the VPT intervention ($p = 0.000$). Improvements in VST, DHI and DHI sub-category scores post-intervention were maintained at 3-months ($p > 0.05$).

External responsiveness results

Figure 4-4 illustrates mean change in scores (mean difference, SE of the mean difference score) between initial to discharge, and discharge to follow-up assessment. Mean change scores showed an improvement between initial and discharge assessment (decreased scores), maintained at follow-up assessment at 3-

months post discharge. Overall, the scores mean change decreased from initial to discharge and follow-up assessments.



Abbreviations: DHI, dizziness handicap inventory; VST, vestibular screening tool

Figure 4-4 Mean change of the VST and DHI (and DHI sub-categories) scores across the continuum of care.

Moderate to high associations were determined (See Table 4-12) between changes in VST scores and changes in DHI scores from initial to discharge assessment after VPT intervention and from discharge assessment to three-month follow-up assessment.

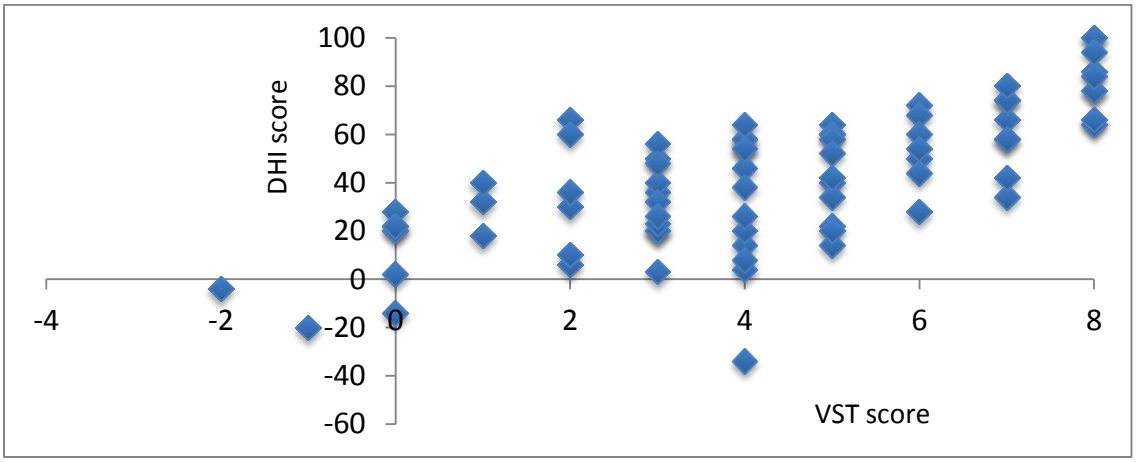
Table 4-12 Correlation of the change in VST and DHI scores between assessment time-points to determine external responsiveness (Paper 3)

	Initial – Discharge VST (n = 76)	Discharge – Follow-up VST (n = 54)	Initial – Follow-up VST (n = 70)
DHI Total	.709**	.709**	.697**
DHI Physical	.758**	.701**	.738**
DHI Functional	.582**	.709**	.657**
DHI Emotional	.595**	.582**	.568**

Abbreviations: DHI, dizziness handicap inventory; VST, vestibular screening tool.
**p ≤ 0.001, *p ≤ 0.005

MCID results

Figure 4-5 displays the high association between the change in VST scores and changes in DHI scores after VPT intervention.



Abbreviations: DHI, dizziness handicap inventory; VST, vestibular screening tool
Figure 4-5 Associations of the change in VST and DHI scores from initial to discharge assessment for people with a vestibular disorder.

Linear regression analysis showed the degree to which the VST score changed compared to the DHI. This analysis determined that a change in the VST score by 1 point (SE = 0.374) is equivalent to a change in the DHI score by 11.63 points (SE = 0.07).

4.3.5 Discussion

This study determined concurrent validity between the VST and DHI and that the VST is responsive to change in symptoms after VPT intervention, similar to the changes in DHI scores. Moderate to high associations between the VST with the DHI (and sub-category scores) were identified across the pathway of care (initial, discharge post-VPT intervention and 3-month follow-up assessments) for individuals who initially presented to hospital with dizziness complaints for whom emergent conditions were excluded. Associations were higher for DHI physical and functional sub-categories compared to the moderate association with the emotional sub-category. The higher association with the DHI physical sub-category is not surprising considering the VST items were sourced predominantly from the physical domain of the DHI, in combination with items from the Vestibular Rehabilitation Benefit Questionnaire [420].

The finding that the VST demonstrates concurrent validity with the DHI is important as the DHI is recognised as a valuable and useful instrument for informing clinical outcomes related to dizziness impairment and is widely reported in clinical

research. Various cut-off scores for severity of dizziness have been utilised for the DHI scale. Scores above 26/ 100 represent significant self-report impairment [68], DHI scores between 31-60 indicate moderate severity [370], and those above 50 / 100 have been shown to predict BPPV [322]. The initial assessment scores, which revealed a mean VST score of 5.90 / 8 and a mean DHI score of 51.50 / 100, are consistent with the initial validation study on the VST, which found that a VST score of four (4) or greater (≥4 / 8) indicated likely presence of a vestibular dysfunction [420]. The current study provides further confirmation that higher scores on the VST are likely to be indicative of people with vestibular dysfunction, when people present to hospital with non-emergent complaints of dizziness.

As the VST has a moderate to high association with the DHI, it is likely that VST scores could be associated with reduced balance confidence, functional limitations, falls and lower quality of life, as these relationships have been demonstrated with the DHI [79, 103, 104, 370]. A future study could explore the relationship between VST scores and an individual's balance confidence and functional impairment. This may be of particular benefit when utilizing the VST with community-dwelling individuals who have presented to hospital.

Our findings confirmed our hypotheses that the VST would demonstrate internal and external responsiveness across the continuum of care, in line with recommendations of Husteda and colleagues [341]. The VST showed improvement

in dizziness symptoms after VPT intervention, a requirement for internal responsiveness. This may be explained by the efficacy of VPT intervention but this hypothesis warrants further study. The improvement in VST scores was maintained at three months.

Our findings also indicate that the VST demonstrated external responsiveness to change in dizziness impairment, in line with the DHI. The moderate to high associations between mean changes in scores after VPT, of the VST with the DHI (and for the DHI sub-categories) from initial to discharge, discharge to follow-up and initial to follow-up assessments was expected given the findings presented. The DHI has been shown to be sensitive to change in symptoms post VPT intervention when BPPV presents [287, 425]. The high association between the mean changes in scores of both the VST and the DHI across the treatment period confirmed that the VST was responsive to change in symptoms post VPT when people presented to hospital with non-emergent dizziness complaints.

The current study indicated that a 2-point change on the VST is needed before a clinically important change occurs. Our results show a change of one point on the VST equates to a change of 11.63 on the DHI. As change of at least 18 points on the DHI (95% confidence interval) is required for a true change in self-perceived impairment post intervention to occur [294], this suggests that a change of at least 1.55 points (ie 2 points) (95% confidence interval) on the VST would be required

for a true change in self-perceived impairment post intervention to occur. While this aspect requires further investigation, this is a valuable finding, supporting the view that changes in VST scores can be utilised to guide clinically meaningful improvements and can be replicated by other investigators in future research [341].

For the clinician, the VST could be considered a quick measure of subjective dizziness impairment, for screening people with dizziness for a vestibular dysfunction, or as a measure of change in a person's response to VPT treatment. The clinician should note that the VST might not reflect changes in all health domains – particularly the emotional domain of dizziness impairment. Comprehensive measures of quality of life and the impact of dizziness impairment on a person are still recommended in a non-acute setting. Rather than replace comprehensive measures, the VST offers a brief, quick measure that can be used in busy clinics and hospital settings as well as guide referral to vestibular services.

Study limitations

There were a large number of people with missing data at the follow-up assessments. Whilst all attempts were made to avoid this however this is a pragmatic study. The results may have been impacted however we are confident in the results as linear mixed models were used, allowing all data that was collected to be used in the analysis. An experienced vestibular physiotherapist using video Frenzel equipment, in agreement with the treating medical officer, completed the

diagnostic categorisation. However, an ear nose throat specialist or neurologist did not routinely assess participants, nor were laboratory tests utilized. The VST does not attempt to exclude a central disorder such as stroke, nor discriminate between central and peripheral vestibular disorders. As the VST was only utilised by a physiotherapist further validation studies could involve medical officers and other health professionals. Further testing involving the VST could also occur in other hospital departments and community settings.

4.3.6 Conclusion

This study demonstrated concurrent validity of the VST and DHI with highest associations achieved between the physical domain of the DHI and VST. The VST demonstrated responsiveness to change following VPT intervention, with the improvement in line with the DHI response. The VST could be considered for use as a quick measure of subjective dizziness impairment and to measure responsiveness to change in symptoms after VPT treatment with individuals who present to hospital with non-emergent dizziness complaints.

4.4 COSMIN score for the Vestibular Screening Tool

The VST has been found to have robust clinimetric properties as presented in Paper 2 and Paper 3. The new tool has been tested for construct, content, discriminative and criterion validity, as well as inter-rater and intra-rater reliability, internal

consistency and responsiveness. The COSMIN checklist can measure the quality of the clinimetric properties of the VST [282].

The COSMIN checklist was uniquely utilised in the systematic review (see Section 2.9, Paper 1) to review currently available self-reported questionnaires' clinimetric properties. Therefore, it is also appropriate to score the newly developed and validated VST using the COSMIN checklist. The measurement properties tested in the systematic review have been tested for the VST and include content validity, criterion validity, internal consistency, inter-rater / intra-rater reliability, test-re-test reliability and responsiveness. The COSMIN item scores for each measurement property of the VST are detailed in Appendix E.

The overall scores using the COSMIN checklist for each measurement property of the VST are:

- Content validity: Excellent (+++)
- Criterion Validity: Fair (+)
- Internal consistency: Good (++)
- Inter-rater / Intra-rater reliability: Fair (+)
- Test-retest reliability: No data
- Responsiveness: Good (++)

Test-retest reliability was not assessed in the ED / AME setting. It is possible that symptoms are likely to change relatively quickly in this setting and therefore, it was

felt that this was not an appropriate setting to investigate test-retest reliability. The VST did not achieve an excellent (+++) overall score for criterion validity, internal consistency, and responsiveness. The main contributor to this was the lack of information on missing items and how missing items were handled. This is a limitation of the validity testing and reporting of the VST.

The overall COSMIN score of the VST can be compared to the self-reported questionnaires scores included in the systematic review presented in this thesis (see Section 2.9, Paper 1). The VST had a strong outcome, scoring second behind the VRBQ and above all other self-reported questionnaires. Overall COSMIN scores of: Excellent (+++), Good (++), Fair (+), and Poor (0) can be totalled together for an overall score [292]. The VRBQ scored the highest with a total of 11, the VST scored 9, whilst the remaining eight self-reported questionnaires scored between 1 and 7 for the overall COSMIN score.

After adults with a likely vestibular disorder are identified, referral to a hospital-based physiotherapy vestibular service is possible. The clinical effectiveness of a physiotherapy vestibular service, based in the hospital setting, is the topic for Phase two, which will be described in the next chapter of this thesis.

Chapter 5 Clinical effectiveness of physiotherapy-led hospital-based, vestibular service (Phase two)

5.1 Preamble

The VST could be considered a quick measure of subjective dizziness impairment in the acute hospital setting. Additionally, the VST can measure responsiveness to change in symptoms after vestibular physiotherapy treatment when used with people who present to hospital with non-emergent dizziness. The VST was used clinically at the Prince Charles Hospital (TPCH), where the studies for this thesis were completed. In 2013, TPCH developed a novel physiotherapy-led hospital-based vestibular service. This service included management of individuals with vestibular disorders in the acute hospital setting and / or post discharge from hospital. TPCH was the first hospital in Queensland Health to offer this service.

Whilst the literature review (Chapter 2) highlighted the effectiveness of specific VPT techniques for vestibular disorders in the community context, there is limited literature on the effectiveness of a service in the hospital setting. The current literature also lacked evidence to direct the time to best manage people who present to hospital with a vestibular disorder. Currently, clinical outcomes are unknown for

people managed immediately, who commence treatment whilst in hospital, compared with those referred through a waitlist, who receive delayed intervention post discharge from hospital as an out-patient. This was investigated in Paper 4, titled 'Clinical effectiveness of a physiotherapy-led vestibular service in a tertiary hospital comparing immediate and delayed intervention pathways'. This paper is currently being reviewed for publication in The Laryngoscope.

5.2 Paper 4: Clinical effectiveness of a physiotherapy-led vestibular service in a tertiary hospital comparing immediate and delayed intervention pathways

5.2.1 Abstract

Background: Vestibular disorders are common presentations to hospital Emergency Departments and are not managed optimally.

Aim: To investigate clinical effectiveness of a physiotherapy-led hospital-based vestibular service by assessing initial and longer-term clinical outcomes, and to compare outcomes for immediate and delayed intervention pathways.

Design: Pragmatic, prospective, observational study reporting baseline, discharge and follow-up outcomes.

Setting: Hospital-based vestibular rehabilitation service including emergency / acute settings and those referred to out-patients.

Participants: Adults (n = 193) presenting to hospital with non-emergent dizziness (mean age = 64.21 ± 15.3 years; female = 60%).

Intervention: Vestibular rehabilitation commenced immediately (< 48 hours of hospital presentation) or was delayed (referred and wait-listed for out-patient services, average 22 days). Vestibular rehabilitation comprised a program of exercises, consisting of eye / head movements integrated with balance and mobility exercises designed to promote adaptive vestibular system changes.

Outcome measures: Physiotherapy vestibular diagnostic tests categorised people as vestibular / non-vestibular. Dizziness impairment, functional vestibular ocular reflex, static balance, gait velocity and functional gait were measured at initial presentation, discharge and 3-months post-discharge.

Results: Participants had significantly reduced dizziness and significantly improved functional gait at discharge, which was maintained 3-months post-discharge ($p \leq 0.001$). Both immediate and delayed intervention groups reported significantly reduced dizziness impairment ($p \leq 0.001$) but only the immediate group significantly improved in all mobility measures ($p \leq 0.005$). Resultant symptoms and functional impact of a vestibular disorder did not significantly subside to normal without vestibular rehabilitation, even 3-weeks after presenting to hospital.

Conclusions and relevance: A physiotherapy-led vestibular service was clinically effective in managing people presenting to hospital with suspected vestibular dysfunction with outcomes maintained in the longer term. Immediate intervention allows for quicker improvements in symptoms, and patients' symptoms do not spontaneously resolve whilst waiting for intervention.

5.2.2 Introduction

People presenting to emergency department (ED) with a vestibular disorder may not be optimally managed [13]. Characteristic symptoms and features of vestibular disorders often allow for a bedside diagnosis and immediate intervention. However, many people are discharged home without specific diagnosis, management or referral to an out-patient service [4]. Referral to vestibular physiotherapy (VPT) to manage these disorders is often not routine despite evidence indicating the efficacy of VPT to assist with symptom resolution [253]. For non-emergent causes, assigning effective treatment to manage dizziness has the potential to improve overall public health care costs by reducing the negative impact of ongoing dizziness and sub-optimal functional balance and mobility.

When vestibular disorders are not managed optimally, symptoms of dizziness, vertigo, and imbalance can persist, causing considerable interference with daily activities [253]. Vestibular disorder and its consequences can lead to devastating experiences including loss of balance, falls and fall related injuries [6], and in turn,

increasing morbidity [47] and healthcare costs [8]. The costs associated with management of vestibular disorder are significant [5, 12]. Therefore, it is postulated that people suspected of, or diagnosed with, a vestibular disorder should be considered for VPT, despite this currently not being routine practice.

Vestibular trained physiotherapists use a comprehensive interview, vestibular assessment and specific diagnostic tests [105, 148] to identify specific vestibular disorders, which then inform evidence-based interventions to reduce symptoms of dizziness and unsteadiness [248, 254-256]. Particle repositioning manoeuvres are effective protocols for management of benign paroxysmal positional vertigo (BPPV) [148] and vestibular rehabilitation (VR) has consistent evidence of effectiveness for a wide range of vestibular disorders such as vestibular neuritis, unilateral and bilateral vestibular hypofunction, vestibular migraine and central vestibular causes [232, 248, 257]. VR is a program of graded exercises, consisting of eye and head movements integrated with balance and mobility exercises designed to stimulate the vestibular system. VPT encapsulates both particle repositioning manoeuvres and VR.

It is novel for a physiotherapy-led vestibular service to include vestibular assessment and management in the ED and acute hospital setting, with ongoing treatment post discharge from hospital, in a hospital-based out-patient setting. Vestibular physiotherapists can organize referral to audiologists, psychologists or

neurologists / general medicine specialists, to provide a multi-disciplinary approach. It is unknown if commencing vestibular physiotherapy immediately with people presenting to hospital leads to better outcomes than delayed intervention (which involves a period of being on a waitlist for an out-patient appointment).

A new model of care involving a physiotherapy-led vestibular service commencing in ED and acute hospital settings, with ongoing treatment post discharge from hospital, in a hospital-based out-patient setting, has been developed to address the needs of people presenting to ED / acute hospital with vestibular deficits. The clinical effectiveness of this service warrants investigation. Therefore, the aims of this study were to: (1) Determine clinical outcomes of people with dizziness and effectiveness of the service when people are managed in a physiotherapy-led hospital-based vestibular service by determining short-term (on discharge) and longer-term (3 months post discharge) outcomes after completing VPT; (2) Compare clinical outcomes and effectiveness of VPT (short-term and longer-term) when immediate versus delayed VPT is completed after a hospital presentation.

5.2.3 Methods

Design

A prospective longitudinal observational study was undertaken.

Participants and Setting

People (>18 years) complaining of dizziness who presented to ED of a metropolitan hospital were included. People were excluded if a known cardiac condition or stroke requiring emergency medical management was the cause of their hospital presentation, if they were unable to provide informed consent (intoxication, mental disability, language barrier), or if recent injuries or musculoskeletal conditions limited diagnostic assessment. Participants gave written informed consent. Ethical approvals were gained by relevant institutions.

Outcome Measures

Physiotherapy assessment included a comprehensive subjective examination, an oculomotor examination (spontaneous nystagmus presence, smooth pursuit, gaze evoked nystagmus, saccadic eye movements, skew deviation), vestibular ocular reflex tests (head impulse test, head shaking nystagmus), head impulse, nystagmus, test of skew (HINTS) and positional testing (Hallpike-Dix test and head roll test) [123]. Video Frenzel equipment was used to observe spontaneous nystagmus, gaze evoked nystagmus, head shaking nystagmus and during positional testing for BPPV. A positive test needed to be consistent with presenting history and medical examination.

Outcome measures were applied at three time points (initial, discharge and 3-month follow-up assessment) to determine clinical effectiveness and included subjective and objective measures:

- Vestibular screening tool (VST) [13]: The VST is a reliable and valid tool for use in the acute hospital setting (83% sensitivity and 84% specificity) to screen for non-emergent vestibular disorders when people with dizziness present to hospital. A score of ≥4 / 8 indicates a vestibular disorder [420].
- Dizziness handicap inventory (DHI): A self–reported perception of impairment related to dizziness was obtained [294]. The 25 DHI items are divided into functional, physical and emotional domains that sum to a total score (0-100). Scores above 60 indicate a severe vestibular dysfunction and greater functional impairment. An 18-point difference is suggestive of a clinically important change when managing vestibular disorders [294].
- Activities specific balance confidence short form (ABC-6): Self-rated balance confidence in performing activities of daily living was determined at each time point. The 6-items were scored (0-100%) and the average calculated (out of 100) [381].
- Clinical dynamic visual acuity (DVA): DVA demonstrated compensation of vestibular hypofunction [180]. Head stationary was compared with manual oscillation horizontally at 2Hz. A difference score of 3 or more points is

indicative of impaired gaze stability [178]. Test-retest reliability and inter-rater reliability is excellent (*ICC* = 0.94 and ICC = 0.84 respectively) in young adults and children [179].

- Postural stability: The time (s) each person stood on a foam surface with feet together and eyes closed for a maximum of 30 seconds was recorded.
- Ten metre walk test (10MWT): Gait velocity was measured using the 10MWT. Comfortable walking speed in healthy adults in their 60s is 1.33m / s [387]. The 10MWT was repeated whilst the person turned their head from side to side every three (3) steps, as completed in the functional gait assessment.
- Timed up and go (TUG) [426]: The TUG test guided current falls risk as slower scores on the TUG (>11.1seconds) have been associated with reported falls in people with vestibular disorders [385].
- Functional gait assessment (FGA): The FGA provided a measure of community ambulation. The test has good validity and reliability when used with people with vestibular disorders [398]. Scores of ≤22 / 30 provide 100% sensitivity and 72% specificity to predict prospective falls in older adults [398, 399].

To determine subjective improvement in dizziness, subjects nominated at the discharge assessment, 'improvement' or 'no change / worsening' in subjective

experience of dizziness; and at the follow-up assessment, 'improvements maintained / improved' or 'worsening' in subjective experience of dizziness.

Protocol and Intervention

At the initial assessment point, a vestibular-trained physiotherapist (completed competency-based, 5-day basic and 3-day advanced training courses) completed a diagnostic vestibular assessment, confirming presence of a vestibular disorder, or non-vestibular disorder as the cause to their presentation to ED with dizziness. A positive finding on assessment indicating a vestibular disorder, needed to be consistent with presenting history and medical examination.

Treatment was offered to all people deemed to have a vestibular disorder in the form of customised VPT. Person-specific, customised, goal focused VPT was performed as a combination of habituation (movement-provoking), gaze stabilization (adaptation), compensation (such as visual or somatosensory), postural control exercises, falls prevention and education. In addition, specific particle repositioning manoeuvres for the treatment of BPPV were undertaken when indicated. Participants were referred for ongoing specialist assessment (audiology / ear nose throat / neurology / psychology) as required and treatment may have been offered from these health professionals. Recorded demographic data included gender, age, self-reported falls in past 12 months, and independence with gait (independent indoors, with or without walking aid).

Data management and statistical analysis

Descriptive statistics of participant's demographic characteristics and clinical diagnosis were presented.

Participants were grouped as either 'vestibular' or 'non-vestibular disorder' following the diagnostic assessment. 'Vestibular' classification included one or more of the following 1) positive Hall-pike Dix (BPPV), supine head roll test (BPPV), head impulse test / video head impulse test (acute vestibular neuritis, unilateral / bilateral vestibular hypofunction) [414]; 2) episodic symptoms of fluctuant hearing loss, vertigo, tinnitus or ear blockage confirmed by a specialist (Meniere's disease) [414]; 3) migraine headaches as per international headache criteria and vestibular symptoms of imbalance, vertigo, dizziness or unsteadiness (vestibular migraine) [50]; 4) direction-changing gaze-evoked nystagmus or pure down-beating / up-beating / torsional nystagmus (indicative of central pathology); 5) symptoms of vestibular disorder present without a clear diagnosis (unspecified vestibular). The unspecified vestibular group were referred for further specialist assessment as required. Participants who did not fit these criteria were categorised as 'non-vestibular disorder'.

Participants deemed as 'vestibular' were also categorised based on receiving immediate intervention or delayed intervention [253]. The immediate vestibular group was comprised of those whose assessment was completed within 48 hours of

presenting to hospital with dizziness complaints, while other participants who were referred to out-patients for care, were categorized as delayed intervention.

For the total group, immediate and delayed intervention groups, means and SD of outcome measures completed at initial, discharge and follow-up assessment points were reported. To determine clinical effectiveness, linear mixed models determined significance of the mean difference of outcome measures across the continuum of care (initial–discharge and discharge–follow-up) for the total group. Linear mixed models compared differences in outcome measure scores between the immediate and delayed intervention groups, at each assessment point (initial, discharge and follow-up). The significance level was set at $p < 0.01$ as multiple assessments were undertaken with $p < 0.05$ reported as trending findings. Data were analysed using the SPSS statistical package (Version 23).

5.2.4 Results

Descriptive information about the characteristics of the study population is included in Table 5-1. The immediate intervention group was assessed within 48 hours of presenting to hospital. The delayed intervention group waited on average (mean) 22 days for an initial assessment, ranging between 3 and 77 days. Of those who completed a discharge assessment, the immediate intervention group completed an average of 3.28 VPT sessions (conducted over an average of 55 days) and the delayed group completed 3.24 sessions (conducted over an average of 52 days).

Table 5-1 Demographics and clinical characteristics of participants

Characteristic	Total group (n = 193)	Immediate intervention (n = 112)	Delayed intervention (n = 81)
Mean age ± SD (y)	64.21 ± 15.28	63.35 ± 15.92	65.39 ± 14.36
Female, n (%)	115 (59.6)	63 (56.3)	52 (64.2)
Falls past 12 months, n (%)	57 (29.5)	28 (25.5)	29 (36.7)
Independent gait, n (%)	152 (78.8)	77 (77.8)	75 (93.8)
Clinical diagnosis:			
Non-vestibular, n (%)	37 (19.17)	22 (19.64)	15 (18.52)
Vestibular: n (%)			
- BPPV	82 (42.5)	46 (41.1)	36 (44.4)
- Vestibular neuritis	28 (14.5)	20 (17.9)	8 (9.9)
- Unilateral vestibular hypofunction	13 (6.7)	7 (6.3)	6 (7.4)
- Bilateral vestibular hypofunction	3 (1.6)	3 (2.7)	0 (0.0)
- Vestibular migraine	7 (3.6)	3 (2.7)	4 (4.9)
- Meniere's disease	3 (1.6)	2 (1.8)	1 (1.2)
- Central	4 (2.1)	4 (3.6)	0 (0.0)
- Motion sensitivity	3 (1.6)	1 (0.9)	2 (2.5)
- Unspecified vestibular	13 (6.7)	4 (3.6)	9 (11.1)

Abbreviations: BPPV, benign paroxysmal positional vertigo.

Independent gait: independent indoors, with or without walking aid.

Of the 156 diagnosed with a vestibular disorder, 105 (67.3%) completed a discharge assessment. Seventy-three (69.5%) of those who completed a discharge assessment, also completed a three-month follow-up assessment. Of the 90 participants in the vestibular group who received immediate intervention, 67 (74.4%) completed an initial and a discharge assessment and 44 (65.7%) of these participants completed a follow-up assessment. Of the 66 participants receiving delayed intervention, 38 (57.6%) completed a discharge assessment, and 29 (76.3%) also completed a follow-up assessment. The main reasons provided for not completing a discharge assessment were symptom resolution, transport difficulties, or patient sought treatment elsewhere. The reasons provided for not returning for a 3-month follow-up were "symptoms resolved therefore don't want to return", "transport difficulties", "interference with work / family matters".

Initial assessment outcome measure scores (mean, SD) for the non-vestibular group are: VST (2.1, 2.5), DHI Total (21.7, 21.8), DHI Physical (7.0, 6.6), DHI Functional (8.7, 9.1), DHI Emotional (6.0, 7.8), ABC-6 (64.3, 32.0), DVA (2.4, 1.4), static balance (13.5, 13.2), 10MWT velocity (1.0, 0.5), 10MWT with head turns velocity (1.1, 0.5), TUG (12.0, 6.6), FGA (22.4, 8.4). Data presented in the following figure and tables relates to those with vestibular disorder only as the non-vestibular group did not require VPT.

There were no significant differences in subjective rating scale results between the immediate and delayed groups (p = 0.50). Results from the subjective improvement in symptoms scale for the total group, and the immediate and delayed groups, at discharge are shown in Figure 5-1 and at a 3-month follow-up assessment are shown in Figure 5-2.

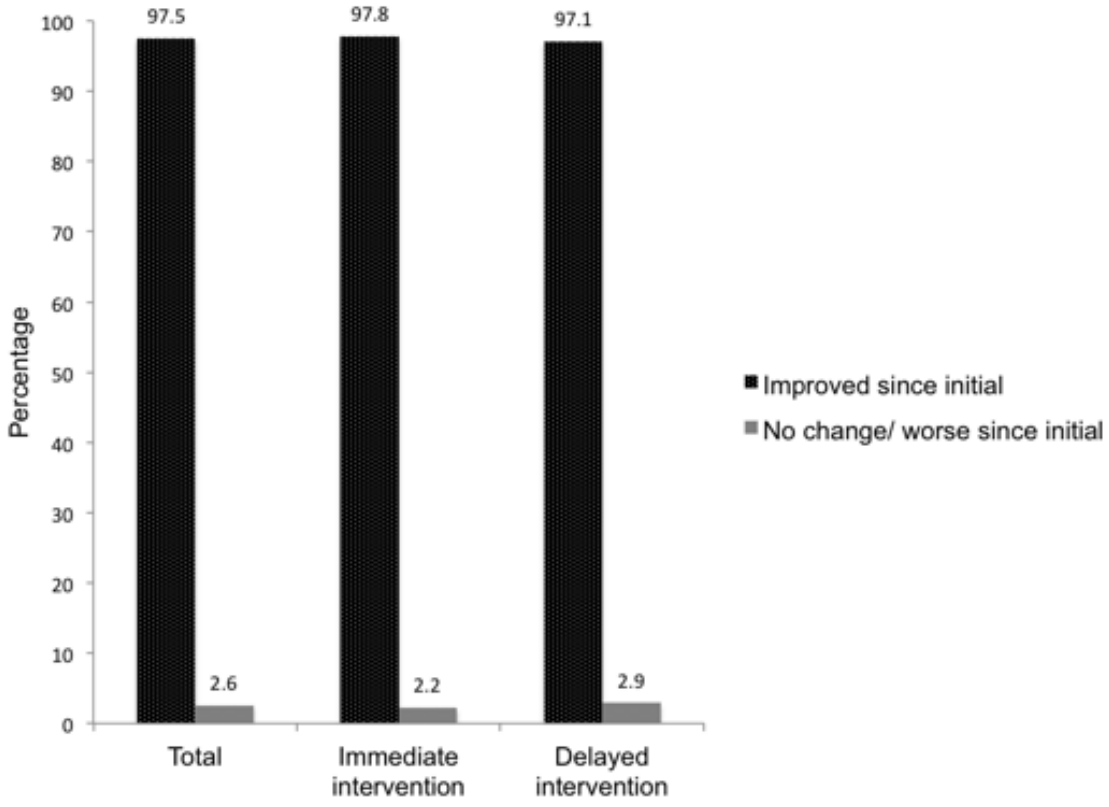


Figure 5-1 Subjective improvement after physiotherapy vestibular rehabilitation at discharge.

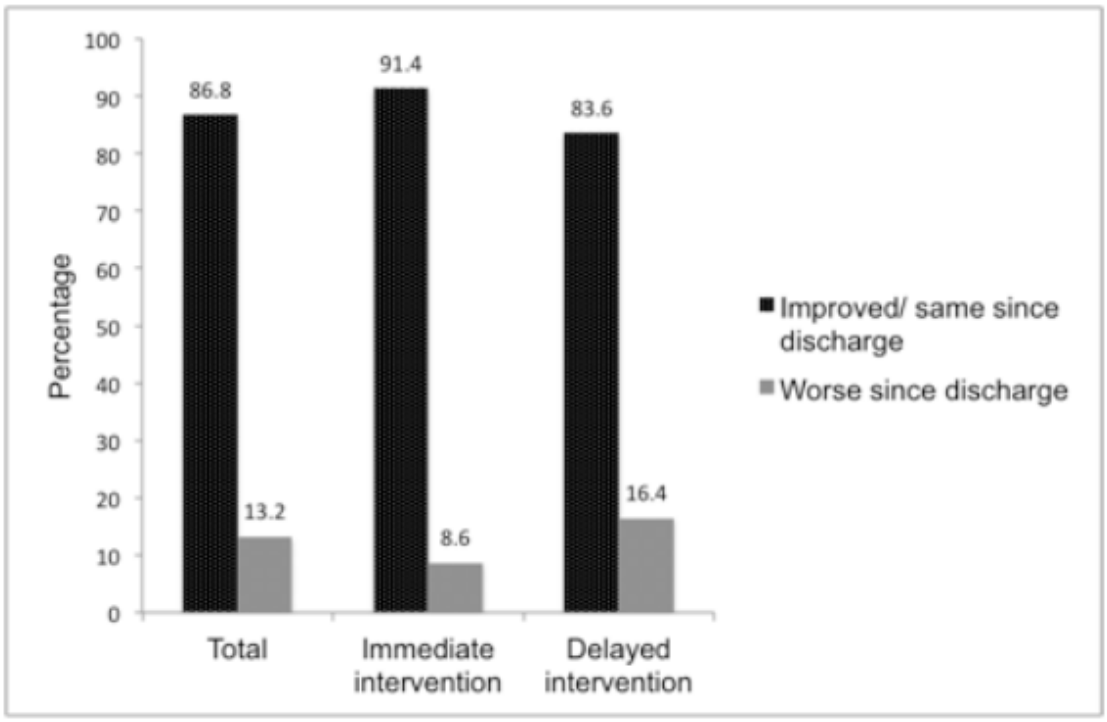


Figure 5-2 Subjective improvement after physiotherapy vestibular rehabilitation at 3-month follow-up.

All outcome measure scores improved significantly after VPT intervention (at discharge assessment) with improvements largely retained three-months after discharge. All outcome measures at follow-up assessment compared to discharge were not significantly different ($p > 0.001$). Table 5-2 highlights the outcome measure scores for participants diagnosed with a vestibular disorder (total group) at three assessment points. Table 5-2 also displays outcome scores after completion of VPT intervention at the discharge, and follow-up assessment points for the total group.

Table 5-2 Mean (SD) initial, discharge and follow-up scores and mean (95% confidence intervals (CI)) differences between assessment points, for participants diagnosed with a vestibular dysfunction (total group)

Outcome measure	Initial assessment	Discharge assessment	Follow-up assessment	Initial – Discharge mean difference (95% CI)	Discharge – Follow-up mean difference (95% CI)
Vestibular Screening Tool (/ 8)	5.4 (2.3)	1.2 (1.6)	1.5 (2.0)	4.3 (3.8, 4.8)**	-0.5 (-1.0, 0.1)
DHI total (/ 100)	50.9 (7.1)	13.2 (16.5)	14.5 (21.4)	39.2 (34.0, 44.3)**	-2.9 (-8.8, 3.0)
DHI physical (/ 28)	16.4 (8.5)	4.3 (5.5)	5.2 (7.2)	12.5 (10.8, 14.2)**	-1.5 (-3.4, 0.5)
DHI functional (/ 36)	19.7 (10.7)	4.7 (6.6)	5.4 (8.6)	15.5 (13.4, 17.5)**	-1.4 (-3.8, 0.9)
DHI emotional (/ 36)	14.8 (10.4)	4.2 (6.4)	4.3 (7.1)	11.2 (9.3, 13.1)**	-0.8 (-3.0, 1.4)
ABC-6 (/ 100)	46.5 (32.1)	79.2 (22.1)	73.2 (28.5)	-33.4 (-38.9, -27.9)**	7.2 (0.9, 13.4)
Dynamic visual acuity	3.6 (2.8)	2.5 (1.7)	2.0 (1.6)	1.6 (0.7, 2.5)**	-0.0 (-0.9, 0.8)
Static balance (s)	11.4 (13.0)	21.4 (12.4)	22.9 (11.1)	-10.1 (-12.8, -7.4)**	-1.4 (-4.6, 1.8)

10MWT velocity (m/s)	1.0 (0.3)	1.2 (0.2)	1.2 (0.2)	-0.2 (-0.3, -0.1)**	-0.0 (-0.1, 0.1)
10MWT head turns velocity (m/s)	0.85 (0.3)	1.1 (0.3)	1.1 (0.3)	-0.2 (-0.3, -0.1)**	-0.0 (-0.1, 0.1)
Timed up and go (s)	11.5 (5.3)	9.2 (3.2)	9.6 (3.5)	1.9 (1.2, 2.7)**	0.1 (-0.7, 0.9)
Functional gait assessment (/ 28)	16.7 (10.1)	26.3 (4.9)	25.0 (6.8)	-9.7 (-11.5, -8.0)**	1.4 (-0.7, 3.5)

Abbreviations: ABC-6, activities specific balance confidence short form; DHI, dizziness handicap inventory; 10MWT, ten metre walk test. ** $p \leq .001$

Outcome measures for the immediate and delayed intervention groups at three assessment points, are shown in Table 5-3. The immediate group significantly improved between assessment points in all outcome measures (all $p \leq 0.001$, DVA $p = 0.004$). The delayed group demonstrated significant improvements between assessment points in the VST ($p \leq 0.001$), DHI total ($p \leq 0.001$) and DHI subgroups ($p \leq 0.001$), ABC-6 ($p \leq 0.001$), FGA ($p \leq 0.001$), static balance ($p = 0.007$), and 10MWT with head turns velocity ($p = 0.007$). The 10MWT velocity was a trending difference ($p = 0.036$), whilst the DVA ($p = 0.350$), and TUG ($p = 0.146$) for the delayed intervention group were not significantly different between assessment time points.

There were no significant differences between the immediate and delayed intervention groups after VPT intervention, at discharge and follow-up assessments for all outcome measures. There were however, some significant differences between groups on initial assessment (VST, DHI Physical, ABC-6, FGA) as displayed in Table 5-3. The delayed group had better scores at initial assessment on the VST, DHI physical sub score, ABC-6 and FGA.

Table 5-3 Mean (SD) initial, discharge and follow-up scores for immediate and delayed intervention groups, and mean differences (95% confidence intervals (CI)) between immediate and delayed intervention groups, for people diagnosed with vestibular disorder.

Outcome Measure	Assessment point	Immediate Intervention Mean (SD)	Delayed Intervention Mean (SD)	Difference between Immediate and Delayed Intervention Mean difference (95% CI)
VST	Initial	6.0 (2.0)	4.4 (2.3)	1.4 (0.8, 2.1)**
(/ 8)	Discharge	1.0 (1.5)	1.5 (1.7)	0.1 (-0.7, 0.9)
	Follow-up	1.5 (2.0)	1.5 (1.9)	0.4 (-0.5, 1.2)
DHI total	Initial	55.6 (27.4)	44.8 (25.6)	10.7 (3.0, 18.3)
(/ 100)	Discharge	11.1 (14.4)	16.4 (19.1)	-1.1 (-10.5, 8.2)
	Follow-up	13.3 (19.8)	16.4 (24.2)	2.2 (-7.8, 12.2)
DHI physical	Initial	18.3 (8.6)	14.0 (8.0)	4.2 (1.8, 6.7)**
(/ 28)	Discharge	3.8 (4.6)	5.0 (6.7)	1.2 (-1.8, 4.2)
	Follow-up	5.3 (7.3)	5.1 (7.1)	1.3 (-2.0, 4.5)
DHI functional	Initial	21.4 (10.8)	17.4 (10.3)	4.2 (1.2, 7.3)
(/ 36)	Discharge	4.0 (5.5)	5.9 (7.9)	-0.9 (-4.6, 2.8)
	Follow-up	5.1 (8.3)	6.0 (9.0)	0.6 (-3.4, 4.6)
DHI emotional	Initial	15.9 (10.8)	13.4 (9.8)	2.2 (-0.6, 5.1)
(/ 36)	Discharge	3.3 (5.7)	5.5 (7.7)	-1.3 (-4.8, 2.2)
	Follow-up	3.2 (5.5)	6.3 (9.0)	-0.7 (-4.5, 3.1)
ABC-6	Initial	36.9 (32.3)	58.0 (28.0)	-19.4 (-28.9, -10.0)**

(/ 100)	Discharge	82.9 (17.1)	73.8 (27.3)	4.5 (-6.3, 15.3)
	Follow-up	72.8 (28.4)	73.8 (29.2)	-1.0 (-13.0, 10.9)
DVA	Initial	3.8 (2.8)	3.3 (2.8)	0.7 (-0.7 2.0)
	Discharge	2.7 (1.5)	2.0 (2.0)	0.8 (-0.9, 2.4)
	Follow-up	2.3 (1.8)	1.6 (1.6)	0.1 (-1.1, 1.4)
Static balance	Initial	8.5 (12.1)	14.6 (13.3)	-5.1 (-9.3, -0.9)
(s)	Discharge	22.0 (11.8)	20.5 (13.3)	3.9 (-1.0, 8.8)
	Follow-up	24.0 (10.5)	21.2 (11.9)	1.8 (-4.0, 7.6)
10MWT velocity	Initial	1.0 (0.3)	1.0 (0.3)	-0.1 (-0.3, -.0)
(s)	Discharge	1.2 (0.2)	1.2(0.2)	0.0 (-0.1, 0.2)
	Follow-up	1.2 (0.3)	1.2 (0.2)	-0.2 (-0.1, 0.1)
10MWT head	Initial	0.9 (0.3)	0.8 (0.3)	-0.1 (-0.2, -0.0)
turns velocity	Discharge	1.1 (0.2)	1.1 (0.3)	-0.0 (-0.1, 0.1)
(s)	Follow-up	1.1 (0.3)	1.1 (0.3)	0.0 (-0.1, 0.2)
Timed up and go	Initial	12.6 (6.4)	10.7 (4.1)	2.0 (0.4, 3.5)
(s)	Discharge	9.2 (3.1)	9.3 (3.4)	0.3 (-1.3, 1.9)
	Follow-up	9.4 (3.4)	9.8 (3.8)	-0.5 (-2.4, 1.3)
FGA	Initial	13.2 (10.4)	21.3 (7.4)	-6.5 (-9.0, -3.9)**
(/ 30)	Discharge	26.5 (4.6)	26.0 (5.2)	1.0 (-2.1, 4.1)
	Follow-up	25.1 (6.6)	24.9 (7.2)	0.2 (-3.4, 3.9)

Abbreviations: ABC-6, activities specific balance confidence short form; DHI, dizziness handicap inventory; DVA, dynamic visual acuity, FGA, functional gait assessment; VST, vestibular screening tool; 10MWT, ten metre walk test. ** $p \leq .001$

5.2.5 Discussion

This study demonstrates that a physiotherapy-led hospital-based vestibular service is clinically effective in managing people who present to a tertiary hospital with complaints of dizziness. In just over three (3) treatment sessions, significant and clinically meaningful improvements in self-reported dizziness, functional gait and balance performances were gained. These improvements were maintained three-months after discharge, in line with the current literature reporting outcomes from vestibular clinics in community settings [148, 253].

These results demonstrated that people presenting to hospital with a vestibular disorder have moderate to severe self-reported dizziness impairment, as measured on the DHI [294] and VST [420]. With an average mean improvement of 39 points on the DHI it is evident that the minimally clinically important difference was exceeded [294]. Additionally, these results also showed that people who present to hospital with a vestibular disorder have significant functional limitations, with an increased risk of falling and poor community ambulation, as revealed by the higher TUG performance (11.4 seconds) than age-related norms [427] and low FGA score (17 / 30) at initial assessment [399]. Almost one third of participants reported at least one fall in the previous 12 months and balance confidence on initial assessment was low, as measured by the ABC-6 (47 / 100) [381]. Scores of the DHI (11.7 points) and VST (1.6 points) after VPT on discharge assessment were within

normal limits, with this improvement maintained 3-months after discharge. Similarly, FGA, TUG scores and ABC-6 scores improved after VPT to within normal limits [381, 426] and were maintained 3 months after discharge. The slight deterioration in scores at follow-up, whilst not significant in this study, could be contributed to a reported 26% recurrence rate of vertigo in patients with vestibular neuritis, including 15.3% of people with vestibular neuritis resulting in BPPV [48].

Despite the immediate intervention group receiving a vestibular assessment within 48 hours of presenting to hospital, and the delayed group waiting on average 22 days, our results showed that both the immediate and delayed groups made significant improvements in self-reported dizziness impairment (VST, DHI, DHI sub-categories), balance confidence (ABC-6) and functional mobility (FGA). While the immediate group made significant improvements in all measures after VPT, the delayed group did not significantly improve in the functional vestibular-ocular reflex (DVA), or mobility as measured by the TUG. The difference between the immediate and delayed groups for these measures however, was not significant or clinically important. Despite only the immediate group improving significantly in all measures after VPT, there were no significant differences between the immediate and delayed groups after VPT, demonstrating that both groups achieved normal scores by discharge, which were maintained 3 months later.

Interestingly, there were no differences on initial assessment between the immediate and delayed group in self-reported dizziness impairment (DHI total), gaze stability (DVA), static balance and gait (feet together and eyes closed on foam, TUG, 10MWT velocity). This indicates that the resultant symptoms and functional impact of a vestibular disorder do not significantly subside to normal levels without VPT, even 3 weeks after presenting to hospital. Thus, it is critical that all people with dizziness are referred even if not immediately managed. While the people receiving delayed intervention had better initial scores than those managed immediately, scores revealed a vestibular impairment (VST) [420] persisted, along with fear of falling (ABC-6) [381], and risk of falling (FGA) [399]. When vestibular physiotherapy is not available to commence in the acute hospital setting with this patient group, a referral to vestibular physiotherapy post discharge is appropriate to allow effective management to help improve symptoms and functional mobility.

The findings of this study may direct further research in the use of vestibular physiotherapy in the acute hospital setting. It remains unknown the effect vestibular physiotherapy has on assisting diagnosis in the acute hospital setting or the cost to the individual and health service when delays to commencement of treatment occur. Additionally, large studies are needed to determine the prevalence of vestibular disorders in ED and the best intervention strategies and referral pathways for clinicians to use when people with dizziness present to ED.

Study limitations

A high number of people did not return for follow-up assessments. This may have impacted results, however linear mixed models was used which allows for participants data to remain included despite having a missing data point. Therefore, we are confident in the accuracy of the findings. Independent vestibular assessment to categorise participants as vestibular or non-vestibular would strengthen the methodology of this study. The results were reported for a mixed diagnostic group, however this is a pragmatic study reporting on people presenting to hospital with non-emergent vestibular disorder. Randomisation of participants to an immediate or delayed intervention group would be beneficial to investigate for future studies. While spontaneous recovery may underpin some improvement with people who underwent VPT, this is unlikely to be a major factor in the management of dizziness as the DHI was high at initial assessment for those in the delayed intervention (similar to those immediately treated). It remains unknown however, the degree of improvement achieved due to spontaneous recovery.

5.2.6 Conclusion

A physiotherapy-led vestibular service demonstrated clinical effectiveness in the management of people with dizziness presenting to hospital, with improvement in symptoms and function, maintained in the longer term. Both immediately delivered and delayed VPT intervention resulted in significant improvement in self-reported

dizziness impairment, balance confidence and functional mobility, supporting the need for referral for VPT. People presenting to hospital with a suspected vestibular disorder should be considered for referral to a physiotherapy-led vestibular service in the hospital setting.

Chapter 6 Synthesis of findings, clinical implications, limitations and future directions

Four papers were included as part of this thesis with the specific findings and implications developed within each paper (see Section 2.9 and Chapter 4 and Chapter 5). This chapter aims to expand on the discussions in each paper, and provide a broad synthesis of the research project in its entirety. An overview of significant findings of the thesis, including comparisons and contrasts with existing literature will be provided and the clinical implications of the research will be detailed. A discussion on the limitations of the research program will follow along with the directions for further research. The discussion will then be drawn to a close with concluding remarks.

6.1 Overview of significant findings

The broad aim of this thesis was to improve the vestibular service model of care, including the screening process as well as clinical management of people presenting to hospital with a non-emergent vestibular disorder. The focus was on adults who present to hospital with a vestibular disorder because 1) dizziness, vertigo and vestibular disorders are common [2, 3]; 2) the consequences of vestibular disorders

are debilitating to the individual [6, 7] and costly to society [5, 8]; and 3) vestibular disorders are not routinely screened for in adults presenting to hospital with symptoms of dizziness and vertigo [4] and therefore are not managed optimally in the acute hospital setting [194].

An overview of the novel significant findings of this thesis are highlighted in this section including comparisons and contrasts with existing literature. The systematic review that was completed as part of this thesis (see Section 2.9) revealed the need for the construction and validation of a new patient-reported screening tool for use in the ED / AME to identify likely vestibular disorders in people who present to hospital with dizziness. The construction and validation studies of the VST formed the basis of Phase one of this thesis. The literature to date was limited in its investigation of the clinical effectiveness of a physiotherapy-led vestibular service in the hospital setting and this formed the basis for Phase two of this thesis. Furthermore, there was a lack of literature to guide the appropriate intervention pathway of people who presented to hospital with dizziness. Phase two therefore also investigated if people require physiotherapy vestibular assessment and management whilst they are in hospital or if there is no difference to clinical outcomes if people have delayed assessment and treatment in the out-patient setting, post discharge from hospital.

One intended outcome of the thesis, on a practical level, was to improve the identification process of non-emergent vestibular disorders in ED / AME. A screening process may limit the number of people who go undiagnosed, when they present to hospital with complaints of dizziness. In identifying people as having a vestibular disorder, a referral to a physiotherapy vestibular service in the hospital setting is possible. The results of this thesis may practically alter ED / AME's screening processes of people with dizziness complaints in ED / AME, and improve referral strategies, to include timely vestibular physiotherapy intervention.

On a theoretical and practical level, the second intended outcome of the thesis was to extend what is known about the clinical outcomes of physiotherapy management for non-emergent vestibular disorders in the hospital setting. Finally, a third intended outcome was to contribute to the knowledge about early VPT intervention and effects on clinical outcomes for people with vestibular disorders.

6.1.1 Questionnaires associated with vestibular dysfunction

The aim of the systematic review included in this thesis (see Section 2.9) was to identify any patient-reported questionnaire that could be applied in the ED / AME setting to screen people with dizziness for a vestibular dysfunction. It was hypothesised that whilst several patient-reported questionnaires would be identified that exhibit validity and reliability, no patient-reported questionnaire

would be identified that is appropriate for use in the ED / AME as the currently available questionnaires would be lengthy or lack validation in this setting.

A strength of the SR was that the COSMIN framework was utilised for the review. This is the first systematic review of patient-reported questionnaires for vestibular dysfunction, dizziness or vertigo that utilised a guideline to evaluate the methodological quality of health related patient-reported questionnaires with the COSMIN framework utilised for the review. While there have been several other systematic reviews completed recently utilising the COSMIN framework [428-431], none of the systematic reviews were in the field of vestibular disorders.

In comparing the systematic review completed as part of this thesis, and that completed by Fong and colleagues in 2015 [291], both showed the DHI to be the most widely utilised patient-reported questionnaire of dizziness and vertigo in the literature. In contrast, Fong and colleagues (2015), only included patient-reported questionnaires for assessing the effectiveness of VPT, and only provided an evaluation on the clinimetric properties for the four most commonly used patient-reported questionnaires [291]. Therefore, Fong and colleagues (2015) did not report on several patient-reported questionnaires, which have been found to have validity and reliability testing completed, such as the VRBQ. In the systematic review of this thesis, the COSMIN framework was uniquely utilised and a greater number of questionnaires were included. Additionally, the VRBQ was shown to

have the highest COSMIN score indicating the highest quality of the clinimetric properties. Therefore, the VRBQ would have been the vestibular questionnaire of choice if clinical effectiveness was being considered alone as part of this thesis.

Another unique aspect of the systematic review included in this thesis was the aim to investigate the clinical utility of measures in the ED / AME. No other systematic reviews have reported on this topic, therefore the finding that no patient-reported questionnaire was deemed appropriate, as a screening tool for dizziness / vertigo in the ED / AME, is an original contribution to the field of vestibular research.

The results from the systematic review included in this thesis are clinically relevant and can guide the clinical selection of patient-reported questionnaires. We recommend the VRBQ be primarily considered for reviewing patient outcomes post VPT. The VRBQ was not selected as the primary questionnaire for the clinical effectiveness study as part of this thesis, as the VRBQ was not appropriate for both Phase one and Phase two. Additionally, the VRBQ was not appropriate for validation studies of the VST as the VRBQ target both pre and post intervention stages. The DHI was selected as the gold standard for the VST validation studies, and clinical effectiveness investigation, as the DHI has robust clinimetric properties and has been widely validated with vestibular disorders, as shown in the systematic review of this thesis. However, for future research into the clinical effectiveness of a

vestibular service, the VRBQ would be an appropriate measure to capture change in symptoms.

The results of the systematic review prompted the construction and validation of a new patient-reported questionnaire, for the purpose of identifying vestibular disorders in people who present to hospital with dizziness / vertigo complaints.

6.1.2 Construction and validation of the new tool

The primary research aim of Phase one of this thesis was to develop a valid and reliable screening tool to identify non-emergent vestibular disorders in the acute hospital setting. It was hypothesised that after the construction of the VST high scores would indicate the likelihood of a non-emergent vestibular disorder; unidimensionality and internal consistency would be demonstrated, along with concurrent validity with the DHI; high inter-rater and intra-rater reliability when tested with physiotherapists; responsiveness to change would be demonstrated after VPT intervention and be in-line with changes in the DHI; and a small VST score change would indicate a MCID.

In comparing the overall COSMIN score of the VST, to the scores of patient-reported questionnaires included in the systematic review presented in this thesis (see Section 2.9 and Appendix E), the VST had a strong outcome, scoring second to the VRBQ and above all other included patient-reported questionnaires. The overall COSMIN scores of measurement properties are able to be totalled together to

provide an overall score [292]. The VRBQ's overall score was the highest with a total of 11, the VST scored 9, whilst the remaining 8 patient-reported questionnaires scored between 1 and 7.

The construction of the VST was determined on patient scores on the DHI and VRBQ (Part A), expert opinion utilising experienced clinicians working in the field, and multi-step statistics including the Rasch model, factor analysis, and binary regression model. As a result, the 4-item VST demonstrated construct validity, unidimensionality and high internal consistency. The VST underwent comprehensive validity testing compared with other questionnaires such as the vestibular activities and participation measure; the vertigo, dizziness, imbalance questionnaire; and the vestibular activities of daily living questionnaires, which were all developed solely from expert opinion [295, 299, 300]. The VRBQ, along with the vertigo symptom scale and the vertigo handicap questionnaire were constructed based on patient interviews utilising factor analysis [70, 298, 419].

Both the VRBQ and the VST utilised the DHI as the gold standard for concurrent validity due to the DHI's sound clinimetric properties and worldwide utilisation [296, 420]. Moderate to high associations between the VST with the DHI (and sub-category scores) were identified across the pathway of care (initial, discharge post-VPT intervention and 3-month follow-up assessments) for individuals who initially presented to hospital with dizziness complaints. Associations were higher for the

DHI physical and functional sub-categories compared to the moderate association with the emotional sub-category. The higher association with the DHI physical sub-category is not surprising considering the VST items were sourced predominantly from the physical domain of the DHI, in combination with items from the VRBQ.

The VST was tested for inter-rater and intra-rater reliability, which was shown to be high, whereas the VRBQ and the DHI have not been tested for inter-rater and intra-rater reliability [294, 296]. Whilst both the VRBQ and DHI were tested for test-re-test reliability, it was not appropriate for the VST to be examined for this clinimetric property due to the fluctuating nature of acute vestibular disorders [294, 296, 420] and due to time limitations placed upon the research from institutional human research and ethics committees (see Section 6.3.2).

The VST was tested for responsiveness using linear regression analysis and VST scores were shown to improve as dizziness symptoms resolved with VPT. The VST scored higher for responsiveness on the COSMIN checklist, compared to the VRBQ. VRBQ's poor COSMIN score was due to the statistical method using effect sizes and the lack of hypotheses for this parameter as reported in Paper 1. The COSMIN guideline considers the use of effect sizes as an inappropriate measure of responsiveness [282]. The panel of experts who determined the COSMIN guidelines, considered that effect sizes 'interpret changes in health status, or interpret

magnitude of an intervention, rather than measures of quality' of the patient-reported questionnaire [282].

The research from Phase one of this thesis has provided clinicians with a valid tool for use in the ED / AME to assist in identifying people with a likely vestibular disorder, which then enables referral to physiotherapy services for vestibular assessment and management. The tool can be adopted clinically to screen adults presenting to hospital with non-emergent dizziness / vertigo symptoms for a vestibular disorder. The VST demonstrated robust clinimetric properties, therefore, is appropriate to be adopted for use in future research.

The VST can also be used as a valuable and useful instrument for informing clinical outcome related to dizziness impairment. The VST can be adopted as a measure of change in vestibular disorder symptoms, after VPT intervention. Changes in VST scores can be used to guide clinically meaningful improvements and can be replicated by other investigators in future research.

Studies of Phase one of this thesis confirm the VST is a valid tool to assist with screening and subsequent referral of adults with a likely vestibular disorder after presentation to hospital with dizziness. Therefore, after identification and referral of appropriate patients, the research questions that follow are: What is the clinical effectiveness of a physiotherapy-led hospital based vestibular service? Do patients who receive immediate intervention, whilst in hospital have better clinical

outcomes than those who are placed on a waitlist to receive delayed intervention post discharge from hospital? Phase two of this thesis addressed these questions and are discussed below.

6.1.3 Short and longer-term outcomes of a physiotherapy-led hospital-based vestibular service

The primary research aims of Phase two of this thesis were to determine the clinical effectiveness and short-term and longer-term outcomes of people completing VPT in a physiotherapy-led vestibular service. It was hypothesised that the hospital-based vestibular service would produce clinically effective results after VPT, with 95% of people achieving significant benefits, returning to normal limits, with maintenance of results in the longer-term (3 months after discharge).

There have been very few clinical studies investigating the effectiveness of vestibular physiotherapy for adults with acute vestibular disorders, as detailed in Chapter 2. This is the first study to investigate the clinical effectiveness of vestibular physiotherapy in the hospital setting, with people as they present to hospital with acute symptoms.

Paper 4 reported that adults who present to hospital with a vestibular disorder have moderate to severe self-reported dizziness impairment and significant functional limitations with an increased risk of falling and poor community ambulation. These

findings were comparable to previous studies undertaken in the community setting with people with vestibular disorders [67, 253, 432].

Clinical outcomes post VPT in the hospital setting

Paper 4 of this thesis (see Section 5.2) found the physiotherapy-led hospital based vestibular service to be clinically effective in managing people with vestibular disorders, who presented to hospital with complaints of dizziness / vertigo. Over 95% of people reported an improvement in symptoms after intervention from the vestibular service. Significant and clinically meaningful improvements in self-reported dizziness impairment (subjective improvement, VST, DHI), functional gait (FGA, 10MWT, 10MWT with head turns, TUG) and balance performance (static balance feet together on foam) were gained in the physiotherapy-led hospital-based, vestibular service. A prospective randomised trial similarly found that VPT was beneficial for people with acute peripheral vestibular disorders after presentation to ED [279].

Additionally, improvements in vestibular function were found for people with acute vestibular neuritis recruited from an ED setting who participated in a supervised VPT program, completed three times a week for 45 minutes per session [433]. Similar improvements in vestibular function were demonstrated in this thesis with only three supervised sessions and a home exercise program. This treatment approach could be argued to be in line with 'real-world' practice capabilities.

Improvements gained from the physiotherapy-led vestibular service were retained with 87% participants either maintaining or making further improvements in the longer-term, three months post discharge from the vestibular service. These findings are similar to longer-term benefits following community based VPT [248].

Paper 4 of this thesis also found that after attending a hospital-based, physiotherapy-led vestibular service, people had a low falls risk and lower risk of prospective falls as measured by the FGA and TUG, which was maintained for 3-months. Furthermore, balance confidence improved to normal limits and was also maintained for three months post discharge. VPT programs have previously been shown to improve balance function to normal levels in people with recent unilateral vestibular dysfunctions [280].

Average number of physiotherapy sessions

Three to four VPT sessions on average can be expected to yield positive outcomes when managing people referred to a physiotherapy vestibular service, after presenting to hospital. A newly published clinical guideline outlines that in people with acute or sub-acute vestibular hypofunction one session a week for three to four weeks should be sufficient to result in clinical benefits [248]. This highlights that the intervention provided in this hospital-led physiotherapy vestibular service meets current best practice and suggests that providing a hospital-based vestibular service may be efficient and effective.

6.1.4 Outcomes of immediate and delayed intervention pathways post hospital presentation

The secondary research aim of Phase two was to test the clinical outcomes of people immediately referred to the physiotherapy vestibular service, receiving assessment and treatment whilst they were in hospital compared to those referred through a waitlist, delayed intervention pathway, receiving treatment post discharge from hospital, as an out-patient. It was hypothesised that people who received immediate intervention compared to delayed, would achieve comparable clinical outcomes after VPT. Furthermore, it was hypothesized that those treated immediately would have faster resolution of symptoms and require fewer treatment sessions.

Paper 4 (see Chapter 5) demonstrated that despite a delay in commencing intervention with people with an acute vestibular dysfunction, symptoms, balance and function returned to normal with treatment, comparable to those who were treated immediately. Of note, symptoms of participants in this thesis did not spontaneously resolve after presenting to hospital with a vestibular disorder. On average, those who underwent a delayed intervention pathway waited approximately three weeks to commence VPT. Persistent symptoms and functional deficits were still evident three weeks after presenting to hospital (see Chapter 5). Paper 4 concluded that the symptoms and functional impact of a vestibular disorder did not subside to normal levels without VPT. Additionally, it is hypothesised that

whilst there may be a degree of spontaneous recovery without treatment, the ongoing occurrence of vestibular symptoms without treatment could lead to chronicity of symptoms with secondary diagnosis such as anxiety, depression, and 'persistent postural-perceived dizziness' [141] (see Section 2.5.6).

People presenting to hospital with a vestibular dysfunction, who received delayed intervention, experienced negative effects of the vestibular disorder for longer, compared to those who received intervention whilst in hospital or within 48 hours of leaving hospital (Paper 4). The importance of immediate VPT following ED presentation has previously been demonstrated with 83% of people presenting to ED with vestibular hypofunction who did not have VPT treatment, still requiring medication at three weeks [279]. The findings of previous research and this thesis suggest that if acute vestibular disorders are left untreated, while symptoms may improve, they do not necessarily return to normal levels, even up to three weeks later.

Participants in the delayed intervention group had ongoing balance deficits when they were reassessed 22 days later with the FGA and TUG (see Section 5.2, Paper 4). Marioni and colleagues (2013) also found ongoing balance deficits after 6 weeks in people with unilateral vestibular hypofunction who did not receive treatment, compared to people who received a balance training program [280]. Therefore, results from Paper 4 (see Section 5.2) and this study by Marioni and colleagues

(2013) inform us that physiological spontaneous compensation does not return balance to normal levels after acute vestibular dysfunction if untreated.

The evidence supporting the importance of early VPT after acute vestibular dysfunction is accumulating. Clinicians need to be educated about the benefits of VPT and refer patients appropriately for assessment and treatment from the ED / AME setting. The support for early intervention validates the importance of the VST for screening in the ED / AME setting.

6.2 Clinical implications

The development of an innovative physiotherapy vestibular model of care in the hospital setting resulted from this research. This model of care includes the use of the VST to screen for vestibular disorders amongst people presenting to ED / AME with complaints of dizziness. Following screening, appropriate referral to a physiotherapy vestibular service for early assessment and management was possible. The physiotherapy vestibular service includes a physiotherapist, trained in VPT (completed competency-based, 5-day basic and 3-day advanced training courses), to assist with diagnosis and management of people with a vestibular disorder in both ED / AME and the out-patient setting. If vestibular physiotherapy is not available to commence in ED / AME, a referral to vestibular physiotherapy post discharge should be made to manage people with a vestibular disorder as an outpatient.

This section discusses the current utilisation of the vestibular model of care in the hospital setting, the clinical benefits for the individual and to society, and considerations for establishing a new physiotherapy vestibular service in the hospital setting.

6.2.1 Utilisation of the vestibular model of care in the hospital setting

Prior to the commencement of this research full time vestibular physiotherapy funded positions in hospitals largely did not exist in Australia. Additionally, little if any vestibular equipment was available in the hospital setting, and vestibular physiotherapists did not have a presence in ED / AME. Furthermore, routine screening of people with dizziness to identify vestibular disorders did not occur in the hospital setting resulting in little or no referral to vestibular physiotherapy for assessment and management occurring.

However, since this research program commenced, in Queensland at least, this model of vestibular care is being established in hospitals around the state. Locally, within Queensland, several hospitals have now established permanent senior vestibular physiotherapy positions to provide comprehensive vestibular physiotherapy services including the provision of relevant vestibular equipment. Medical officers, nurses and allied health professionals at hospitals around Queensland and Australia are using or encouraged to use the VST in ED / AME. Physiotherapy vestibular services at several hospitals now provide early

assessment and treatment of people with vestibular disorders. This model of care has potential for wider application and uptake both nationally and internationally.

Physiotherapy models of care

Primary contact physiotherapy models of care for health service delivery are becoming increasingly prevalent within EDs, in particular, the autonomous assessment and management of musculoskeletal injuries. Previous research has shown that primary contact physiotherapists treating musculoskeletal injuries, compared to ED medical staff or nurses, can result in reduced patient waiting time [434], reduced average length of stay [435], reduction in days to return to usual activity [436], good diagnostic accuracy [437], greater patient satisfaction [437], higher referral rates to outpatient physiotherapy for follow-up [438], and improved short term clinical and functional outcomes [437].

In a secondary contact role, physiotherapists in ED evaluate the patient after the medical officer to assess and provide management as required. The role may include determining suitability for discharge with respect to falls risk and mobility status, provide referral onwards to required services, and aiming to reduce unnecessary admissions to hospital [439].

Another model of care is the physiotherapy-led vestibular clinic, assessing and managing patients from an ear, nose, throat specialist waitlist [440, 441]. The vestibular physiotherapy assessment and management occurs instead of the ear,

nose, throat specialist assessment for people with complaints of dizziness and / or imbalance [440, 441]. An ear nose throat specialist is available to discuss patient cases and to provide assessment and treatment as required [440, 441]. This model has been shown to decrease the number of hospital visits and onward referrals, reduce patient waiting times and has high patient satisfaction [440, 441].

The physiotherapy-led vestibular service in the hospital setting, developed in this thesis, revolves around early screening, assessment and management of non-emergent vestibular disorders in the ED and hospital setting. As the models of care highlighted in this section, there are many potential clinical benefits.

6.2.2 Potential consequences of not implementing physiotherapy vestibular model of care

Negative consequences of unmanaged vestibular disorders are great, to both the individual and society (see Section 2.4) [5, 7, 8, 12, 29, 38]. It is common practice for ED / AME medical officers to discharge people with peripheral, non-emergent vestibular disorders, without a specific diagnosis or referral for management [4, 14, 105]. Without a physiotherapy vestibular model of care, patients with dizziness / vertigo presenting to hospital may have lengthy stays in hospital, have unwarranted medical tests to determine a diagnosis, or be discharged from hospital without a specific vestibular disorder diagnosis and therefore appropriate treatment [4, 13, 14]. These patients may receive a referral for follow-up to the general practitioner or the ear nose throat specialist. The waiting time on the ear, nose, throat

specialist's waitlist for a non-emergent vestibular disorder is in the order of months to years [440, 441]. The long waiting time may allow chronic vestibular disorders to develop. This is likely to contribute to higher costs to both the individual and to society as chronic vestibular disorders require a greater number of treatment sessions compared to acute or sub-acute vestibular disorders [248].

6.2.3 Clinical benefits of the physiotherapy vestibular model of care

Providing a physiotherapy vestibular model of care able to manage people presenting to ED with complaints of dizziness has the capacity to optimise care for these people [13]. The physiotherapy vestibular model of care allows for improved access to physiotherapy vestibular assessment and management. Early VPT intervention allows for an improvement / resolution in symptoms and therefore reduces the likelihood of the negative consequences on the individual and society (see Section 2.4).

Individual's benefits from physiotherapy vestibular model of care

For an individual experiencing non-emergent vestibular dysfunction, access to VPT will improve their symptoms, function, activity and participation [42, 207, 248]. However, the earlier VPT is provided the faster the resolution of symptoms to people with non-emergent vestibular disorders, as supported in Paper 4 (see Section 5.2). Regardless though, it is likely that even delayed management is

preferable for people with non-emergent vestibular disorders rather than receiving no management.

Improvement / resolution of vestibular disorder symptoms via VPT is likely to have other benefits for an individual such as reducing the risk of developing depression, reducing the risk of falls and improving quality of life [38, 72-74, 79, 268]. Early VPT intervention can also decrease the need for ongoing medication use [279] and is likely to reduce the number of visits to medical practitioners [38]. Such benefits have broader societal implications.

Societal benefits from physiotherapy vestibular model of care

Improving screening procedures and providing early physiotherapy vestibular intervention in ED / AME may reduce overall health care costs in managing people with vestibular dysfunction. Early vestibular assessment and therefore diagnosis is likely to reduce the high costs associated with diagnosing people with dizziness / vertigo in ED / AME [5, 13]. High costs appear to reflect the high prevalence of dizziness in ED and high rates of imaging use [5]. In ED, there is an overuse of computerised tomography imaging in presentations of dizziness / vertigo [13]. Additionally, there is an overuse of computerised tomography with people diagnosed with BPPV in ED and an underutilisation of magnetic resonance imaging in people with acute vestibular syndrome [13].

It is proposed that early physiotherapy vestibular assessment can assist with diagnosis and therefore facilitate appropriate use of imaging, reducing costs in ED and to the health care provider. Additionally, benefits may include a reduction in unnecessary admissions, reduced hospital length of stay, reduced unwarranted and costly imaging [5], and reduced unwarranted referrals to specialist waitlists [440, 441]. However, this requires further investigation.

6.2.4 Setting up a vestibular model of care in the hospital setting

This thesis illustrates that it is feasible to implement a vestibular model of care in a hospital setting. Successful implementation of a physiotherapy vestibular model of care includes streamlined referrals and early access to assessment and management services for people with vestibular disorders presenting to hospital.

Scope of the vestibular model of care

There are several ways to establish and operate a vestibular service in the hospital setting dependent on the size of the hospital, availability of services and specialists, funding available for resources and support from the head of the physiotherapy department and director of ED / AME. To establish a vestibular service within the hospital setting, education of key stakeholders is important to gain financial support. Hospitals without access to services such as ENT, Neurology, Audiology within the hospital, will need to establish agreements with neighbouring hospitals

or private service providers for access to these services as it is essential to have access to a multi-disciplinary team to manage patients with vestibular disorders.

There are stages for implementing a vestibular service in the hospital setting (see Table 6-1) and variations are likely to exist between hospitals. A hospital with Physiotherapists permanently staffed in ED / AME, who are trained in vestibular management, may have the capacity to assess and treat patients in ED / AME as a secondary contact service, and refer patients for ongoing management to an outpatient vestibular physiotherapy service. Other hospitals may not have physiotherapists staffed in ED / AME with the appropriate skill set or capacity and therefore a funded vestibular physiotherapy position could provide this service to ED / AME as well as follow-up patients in an outpatient setting.

Referral sources to the vestibular model of care

When considering establishing a vestibular service, there are multiple referral sources to a vestibular physiotherapy service in the hospital setting to consider. Referrals may be received from health professionals working in ED/ AME or other wards within the hospital or community services, medical specialist outpatients, ENT specialists, or neurologists. Accepting referrals directly from GP services is likely to be at the discretion of the physiotherapy department/ hospital policy. Some hospitals have primary contact vestibular physiotherapy positions designated to reduce ENT and / or neurology waitlists by assessing and managing patients in a

primary contact capacity. The focus of this thesis is the vestibular model of care in the hospital setting, to manage people presenting to hospital with vestibular disorders.

In regards to the acute vestibular model of care developed in this thesis, referrals from ED / AME are received from medical officers/ health professionals via telephone, often after the use of the VST to assist the referring clinician. The phone conversation allows the physiotherapist (trained in vestibular management) to briefly discuss the case to determine the urgency in which a vestibular assessment is required. For example, a patient who presents with a clinical history suggestive of acute vestibular syndrome and who has stroke risk factors (such as stroke history, smoker, older person) should be prioritised for assessment as soon as possible to assist the medical team in differentiating between a peripheral and central cause. In contrast, an adult forty years of age who presented to ED the previous evening with intermittent positional vertigo, now reporting a decrease in symptoms, is safely mobilising and has been cleared for discharge medically, does not require an urgent vestibular assessment.

The vestibular model of care allows for a vestibular assessment and VPT to be completed either in ED / AME or post discharge in an outpatient setting. When a non-urgent vestibular assessment is required, the vestibular physiotherapist could either complete a vestibular assessment in ED prior to the person's discharge if the

vestibular physiotherapist has time, or they could request for the ED physiotherapist to complete a vestibular assessment (as training allows, see Table 6-1) prior to discharge, or have the patient referred to the outpatient vestibular service for a vestibular assessment to occur post discharge from hospital. The outpatient service may have availability to have the person return for a vestibular assessment within a week, otherwise a phone call at this time would be appropriate to determine the need for a vestibular assessment. Information on reasons when they should return to ED (symptoms return to a severity level warranting ED or neurological / cardiac signs present) should be provided to the person with symptoms suggestive of a vestibular disorder, if they are discharged from ED without a vestibular assessment. Information on private practitioners who are trained in vestibular management may also be provided as an alternate option to waiting for an outpatient appointment at the hospital. When a person is assessed in ED and requires further vestibular physiotherapy management, a follow-up appointment in the outpatient vestibular service should be arranged. To avoid delaying a person's discharge from hospital or prolonging a hospital stay unnecessarily, an outpatient physiotherapy vestibular service for ongoing management is important.

Providing ongoing VPT when required is important to improve or resolve symptoms and avoid the negative consequences that can follow untreated vestibular disorders

(see Section 2.4). Providing ongoing VPT management avoids people representing to an ED / general practitioner with an unmanaged vestibular disorder after being discharged from hospital. The decision of where to complete VPT requires consideration of the patient's safety followed by the most economical location. VPT should continue with the person whilst they are in hospital until they are deemed safe medically and physically for discharge from hospital, with ongoing VPT continuing as required in an outpatient setting (or a day rehabilitation unit). VPT in an outpatient department or day therapy unit is less costly compared to overnight stays in hospital.

Resourcing a physiotherapy vestibular service in the hospital setting

Physiotherapy staff required for the physiotherapy vestibular service depends on the number of ED presentations and size of the hospital and existing ED / AME staff trained in vestibular management with available time. The metropolitan hospital where this thesis was undertaken has approximately 86,000 ED visits / year and has 1 full-time senior physiotherapy position specifically appointed to manage the physiotherapy vestibular service within the hospital. A Monday to Friday (8am – 4:30pm) vestibular service is offered, servicing the hospital (including ED / AME) and a vestibular outpatient service. Additionally, patients in ED / AME are also at times seen by physiotherapy staff permanently located in ED / AME seven days a week, as time and skill sets allows.

The permanently appointed senior vestibular physiotherapist is under the direct management of the head of physiotherapy however this is hospital dependent and alternatively may sit under the management of the ED / AME.

When establishing a new vestibular service within a hospital setting, administration officer staffing should be considered when existing administration officer staffing is not available. Consultations with audiology, psychology, ear nose and throat specialists, neurologists, general physicians working in ED / AME should occur to determine the capacity of the appropriate multi-disciplinary team for managing people with vestibular disorders.

Considerations for implementing a vestibular model of care

This vestibular model of care in the hospital setting can be implemented in stages depending on the level of funding for vestibular staff, equipment available, and competency level of vestibular physiotherapists. In order to implement this model of care successfully there are several considerations worth discussing. The stages of implementation are highlighted in Table 6-1.

Table 6-1 Stages of hospital based vestibular service

Stage	Vestibular service description	Location	Equipment	Proposed training
1	VST implementation with non-emergent people with dizziness, presenting to ED / AME. Staff should be encouraged to refer people who score 4 or greater on the VST to vestibular physiotherapy	Screening in ED / AME	VST in lanyard size to attach to name badge, for easy use	New graduate with minimal clinical experience for use of VST (+/ - medical officers, nursing and allied health staff
2	Outpatient hospital vestibular service assessing patients post discharge from hospital	Outpatient department of hospital	Video Frenzel equipment + / - video head impulse test	Attendance of 2-3 day vestibular physiotherapy course. Work shadow and mentoring from advanced vestibular physiotherapists. Ideally, attendance of competency-based basic vestibular course (5-6 days).

3	Vestibular physiotherapy services for people in ED / AME. Commencement of management of vestibular disorders, such as BPPV and vestibular neuritis whilst person is in hospital	ED / AME. Follow-up treatment is likely to occur in an outpatient service, after the person is discharged from hospital (Stage 2)	Video Frenzel and video head impulse test	Attendance of competency-based basic vestibular course (5-6 days). Clinical experience in assessment and treatment of vestibular disorders.
4	Assisting medical officers in ED / AME to differentiate between peripheral and central disorders	ED / AME and outpatient hospital vestibular service	Video Frenzel and video head impulse test	Attendance at advanced vestibular course (3 days). Work shadow in ED / AME and clinical experience in this setting. May provide mentoring, work-shadow opportunities for others.

Competency of physiotherapists

It is essential for physiotherapists working under this model of care to hold advanced knowledge and skills and have recognised competence in comprehensive management of people in ED / AME for vestibular disorders. To achieve competence, attendance at vestibular competency courses, participation in professional development, and work experience with experienced physiotherapists in this field is recommended.

Attendance of competency-based vestibular courses run over several days by a team of experts in the field including physiotherapists, neurologists, and ear nose throat specialists is recommended. Such competency-based courses include examination to determine competency in assessment and treatment of vestibular disorders.

Certainly in Queensland, in recognition of the need for this service model, a state-wide vestibular collaborative initiative has recently been established to assist with ongoing professional development via regular videoconferences, and development of a self-competency tool to highlight topics requiring understanding.

Post-graduate courses at universities offering vestibular education with work shadowing opportunities are available in Australia. Alternatively, work shadowing experienced physiotherapists in vestibular assessment and management is also recommended. Several days of clinical immersion is recommended in ED / AME,

along with outpatient clinics with the aim of exposure to a wide variety of clinical experiences in vestibular assessment and management.

One key advanced training / competency required for clinicians working in this area is to be able to assist in differentiating emergent and non-emergent conditions. However, as discussed in Section 2.6.5 this can be challenging to achieve so therefore it is essential for a combined medical-physiotherapy assessment to occur in ED / AME. Knowledge and clinical understanding of when to recommend imaging such as magnetic resonance imaging, that is when central findings are noted on assessment in the setting of acute vestibular syndrome, is important. Additionally, experience and confidence to liaise with medical officers in ED / AME regarding recommended referral / assessment by neurologists and / or ear nose throat specialists and / or audiologists, is also required.

An example of physiotherapists working in conjunction with medical officers in management of vestibular disorders is the physiotherapy-led vestibular clinic (see Section 6.2.1), assessing and managing patients from an ear, nose, throat specialist waitlist [440, 441]. Ear, nose, throat consultants are available for joint consultations when required. Another example is the secondary contact model (see Section 6.2.1) where physiotherapists assess patients in ED after medical officers and coordinate assessment findings for management decisions [439].

Multi-disciplinary approach

Managing vestibular disorders requires a multi-disciplinary approach [442]. Therefore, a vestibular service should have access to a multi-disciplinary team for assessment and management including ear, nose, throat specialists, audiologists, neurologists, occupational therapists and psychologists. Presence of ear, nose, throat specialists or neurologists in ED / AME is often non-existent or limited in Australian hospitals [105]. Therefore, assessment and management of vestibular disorders in ED / AME is left to medical officers in ED / AME who may not have expertise or the equipment to elicit, record, or interpret nystagmus as part of the assessment [105]. It is proposed as part of the physiotherapy vestibular model of care, for vestibular physiotherapists to assist the frontline practitioners in ED / AME in assessment, diagnosis and management of vestibular disorders. Additionally, referral processes to audiology services are recommended to assist with ongoing investigations and diagnosis [443, 444].

Barriers to establishing new vestibular services in the hospital setting

Several barriers are likely to be encountered in establishing a new service [445], such as a vestibular service. One such barrier is likely to be a lack of clinicians' awareness and understanding [105] about vestibular disorders. Providing regular education sessions and case discussions to ED / AME staff, are likely to increase

clinician's awareness and understanding [446] of the role of vestibular physiotherapy and the need for such a service for people with vestibular disorders.

Another challenge in establishing a vestibular service is funding staff and equipment. Staff, additional to existing needs, and expensive vestibular equipment may be required to establish a vestibular service. Business case proposals for funding physiotherapy vestibular services in the hospital setting should highlight prevalence of vestibular disorders, the potential negative consequences to the individual and society, and physiotherapy effectiveness in assessment and management of vestibular disorders. The business case should request funding for experienced and senior physiotherapists with vestibular training for successful establishment of such a service. Additionally, vestibular equipment requests should include video Frenzel equipment (see Section 2.6.1.2) and video HIT (see Section 2.6.2). Locally, within Queensland, several hospitals have successfully applied for financial support for physiotherapy vestibular services and equipment in the hospital setting.

6.3 Limitations of the research

It is important to recognise the limitations of this research, so that the results are able to be interpreted within the boundaries of these limitations, and to identify research areas that need further attention. Specific limitations have been

highlighted in each paper (see Sections 2.9.5, 4.2.5, 4.3.5, and 5.2.5). In this section, additional limitations to the research presented in this thesis are discussed.

6.3.1 Study design

Single site study design

Only single site studies were carried out as part of this thesis. Single site studies are less robust and whilst results can be extrapolated to similar settings, multi-site studies would provide stronger evidence to support the findings of this thesis. Several limitations, detailed in this section, could be minimised by the completion of multi-site randomised controlled trials now that there is the evidence of the effectiveness of an inception study.

The main investigator for the studies of this thesis was also the main physiotherapy assessor for the initial, discharge and follow-up vestibular assessments, as well as the primary vestibular physiotherapist who provided treatment. This would have created a level of bias and therefore further research is required utilising multiple sites and therapists as well as independent assessors to reduce this level of bias.

Cognition testing

The exclusion criteria applied in the studies comprising this thesis, included 'unable to provide informed consent (intoxication, mental disability, language barrier) however specific guidelines were not specified for cognition. Participants were not tested for their cognitive status using a validated screening test such as the

standardised mini mental state examination [447]. Therefore, it is possible that people with lower cognitive function or mild dementia were inappropriately included in the VST validation studies and the clinical effectiveness and comparison of intervention pathway studies. However, as all people recruited to the studies reported in this thesis, were able to give a detailed history of their presenting symptoms when interviewed, it is unlikely that cognitive impairment was an issue.

Face validity of VST

The VST is limited in its face validity as only minimal input during the pilot testing phases was gained from people with a vestibular disorder in the ED / AME setting. The VST was constructed based on patient reported symptoms utilising the DHI (Physical sub-group) and VRBQ (Part A) scores, however, neither measure has been validated in the ED / AME setting. In the development of a new tool, items can be developed based on patient experience and / or on expert opinion. Whilst the utilisation of the DHI and VRBQ scores gave an impression of a patient's opinion, a more robust study design would have included gathering of information from the patient's perspective [284]. Retrospective chart reviews about patient's symptoms, or prospective interviews with a cohort of people from the ED / AME setting with evidence of a non-emergency vestibular disorder, could have been completed.

Immediate and delayed categorisation contamination

Participants with more severe symptoms may have been more likely to be in the immediate intervention pathway. Participants were categorised as being in the immediate or delayed intervention pathway based on when they received a vestibular assessment. It is possible that medical officers and therapists would likely have referred people with more severe symptoms, with a request to see the patient urgently, as they learnt that physiotherapy vestibular intervention might assist with symptoms and therefore discharge from hospital. Thus, people with more severe symptoms could have been more likely to be seen in the ED / AME setting for their initial vestibular assessment and therefore placed in the immediate intervention group. This observation was confirmed by the results presented in Paper 4, reporting the outcomes of the comparison of intervention pathways. People referred to the immediate intervention pathway had significantly worse scores on initial assessment compared to the delayed intervention group on the VST, DHI Physical sub-score, ABC-6, and FGA. One reason for the differences in clinical presentation between intervention groups on initial assessment is the timeframe from onset of symptoms / presentation to hospital and initial assessment. The delayed group waited on average 22 days before an initial assessment and therefore a degree of spontaneous recovery may have occurred with some people. A more robust protocol would ensure all participants receive an

initial assessment whilst they were in ED / AME, to gain baseline measures. This limitation does not impact the conclusions drawn from this study.

Lack of non-treatment group for comparison

The research protocol presented in Paper 4, 'Clinical effectiveness of a physiotherapy-led vestibular service in a tertiary hospital comparing immediate and delayed intervention pathways', does not include a non-treatment group to compare with the treatment group, despite the immediate intervention group being able to be compared with the delayed intervention group. Future research will be considered comparing hospitals with and without a vestibular service to compare and demonstrate the clinical outcomes of a physiotherapy-led vestibular service.

6.3.2 Ethics committee considerations

A number of considerations were made to the protocols and implementation of the studies included in this thesis by relevant Ethics committees. It is recommended that future studies incorporate a brief cognitive screen test for older patients presenting to hospital with vestibular dysfunction. Similarly, test-retest reliability of the VST was not conducted due to time considerations identified by an Ethics committee impacting on ED flow.

Additionally, a timeframe of twenty minutes was used for the inter-rater and intra-rater reliability testing of the VST, which may be considered an inadequate time interval between tests. This timeframe was chosen to avoid delaying treatment and

discharge in the busy ED / AME setting, where reliability testing took place. An ethics committee did not deem a longer timeframe appropriate. A short timeframe was requested to avoid delaying discharge from ED / AME. However, this timeframe may not be reflective or adaptable in other settings in which the VST may be utilised, such as for follow-up visits in an out-patient setting. Additionally, longer timeframes for reliability testing are more feasible with less acutely unwell participants.

6.4 Future directions

Results from this thesis give a clear direction for future research. Firstly, determine if a physiotherapy-led vestibular service is a cost-effective strategy to manage adults presenting to hospital with a vestibular disorder to provide further evidence for the clinical uptake in hospitals nationally and internationally. Secondly, investigating the vestibular physiotherapist's role in ED / AME for differentiating between emergent and non-emergent vestibular disorders in the acute hospital setting. Furthermore, studies investigating prevalence of vestibular disorders in the hospital setting, and application of vestibular services in other hospital contexts such as specialist medical outpatients, are discussed.

6.4.1 Cost-effectiveness of physiotherapy vestibular model of care in the hospital setting

Future research should examine the cost-effectiveness of a physiotherapy-led vestibular service in the hospital setting. Cost-effectiveness analysis refers to a type of economic analysis that examines the relative costs of different courses of action [448]. Cost-effectiveness could be determined using cost utility analysis, expressed as quality adjusted life years as its measure of effect [448]. In this case, cost-effectiveness of providing a physiotherapy-led vestibular service in the hospital setting should be conducted examining immediate versus delayed or no vestibular physiotherapy service. A cost-effectiveness analysis ideally needs to consider a range of factors; including those associated with timing and delivery of the service as well as long-term outcomes both to the individual and to health care systems.

Factors associated with the timing and delivery of the physiotherapy vestibular service in ED that could be considered in a cost-effective analysis may include staffing costs of both medical and physiotherapy staff providing the service, wait times in ED, imaging costs such as computerized tomography, medication prescription, and ongoing referrals to specialist services, number of admissions to hospital after presenting to ED, and hospital length of stay [434, 439]. Analysis has been completed in several studies investigating primary contact physiotherapy models in ED treating musculoskeletal conditions (see Section 6.2.1), which have shown to reduce waiting and treatment times [434]. The physiotherapy-led

vestibular service utilises a similar model so it is reasonable to explore such further research.

Investigating the long-term (12 months to 2 years) clinical outcomes after attending a vestibular service in the hospital setting is also of interest to consider in a cost-effectiveness analysis of the service. Maintenance of clinical improvement, re-occurrence of dizziness / vertigo, rates of re-presentation and re-admission to hospital due to symptoms of vestibular disorder, health care utilisation, and prevalence of those waiting to see a specialist are important to consider [434, 441]. These topics have not been investigated to date and are important, as they are associated with both societal and personal costs [7, 29, 38, 449] (See Section 2.4).

As a cost-effective analysis includes a comparison of interventions, it would be important to track people who present to hospital with dizziness / vertigo who do not receive hospital-based physiotherapy vestibular services. Determining utilisation of health and specialist services as well as length of time spent on specialist waitlists prior to assessment would be of interest [440]. Additionally, the proportion and characteristics of adults whose symptoms resolve compared to those who develop chronic symptoms or develop additional secondary symptoms / diagnoses when initial symptoms are not managed immediately, and determining the burden of these symptoms if left unmanaged are important considerations in future analysis. In gaining a better understanding of these issues it is hypothesised

that further evidence would emphasise the importance of early VPT intervention of adults presenting to hospital with a vestibular disorder.

The cost benefit to the people, who present to hospital with vestibular disorders, could also be investigated. Factors to consider if examining the cost benefit to the service user could include loss of work-days [38], prevalence of development of chronic symptoms, falls and fall related injuries [36], medication use [450], and quality of life [38], anxiety and depression affecting wellbeing [29]. This has not been investigated with people who present to a hospital setting, nor in relation to the improvements a physiotherapy-led vestibular service may yield.

6.4.2 Clinical effectiveness of hospital provided vestibular physiotherapy

Effectiveness of experienced vestibular physiotherapists to assist medical teams in the diagnosis of people with acute dizziness and vertigo symptoms is an important next step for vestibular physiotherapy research. No study has investigated the physiotherapist's role in ED / AME in assisting medical officer's diagnosis of vestibular disorders. It is hypothesised that the vestibular physiotherapist has an important role to assist the ED medical officer's assessment of people with acute dizziness / vertigo. Vestibular physiotherapists in the acute hospital setting have training and experience to assess nystagmus, balance and mobility, and experience in diagnosing and managing vestibular disorders such as BPPV and vestibular neuritis, as well as assessment and treatment for stroke [257, 441]. Additionally,

vestibular physiotherapists have access and knowledge to use equipment such as the video Frenzel and video head impulse test. A combined medical-physiotherapy intervention strategy may prove to be the best solution in managing acute vestibular disorders in the ED / AME.

Physiotherapists' role in differentiating between emergent and non-emergent vestibular disorders

The physiotherapist's role in differentiating emergent and non-emergent disorders for acute vestibular syndrome in the ED / AME needs to be investigated. As detailed in Section 2.6.5, differentiating between peripheral and central vestibular disorders is challenging in the acute hospital setting [105] however physiotherapists with specialist vestibular training are well placed to assist. In a busy clinical context such as ED / AME, an experienced vestibular physiotherapist is more likely than an ED medical officer to utilise video Frenzel equipment and video HIT equipment (see Section 2.6.1.2 and Section 2.6.2) [451], which would assist with diagnosis. Additionally, vestibular physiotherapists specialise in assessing and interpreting eye movements, in assessments such as the HINTS, which has been shown to be more sensitive for detecting early stroke than brain imaging [124].

Physiotherapists' effectiveness to utilise an algorithm to assist diagnosis could also be explored further. Recently an algorithm has been published supporting the differentiation of peripheral and central disorders in people with acute vestibular syndrome [126]. The algorithm is based on the HINTS-plus examination [121] and

recommends use of video Frenzel and video HIT equipment. Vestibular physiotherapists with their expertise in this area may be a useful adjunct to the application of this algorithm in the hospital setting.

Technological advances impacting vestibular assessment / management

The video HIT (see Section 2.6.2) should be prioritised for use in future research in the hospital context. The video HIT is more sensitive and specific for examining vestibular hypofunction compared to the bedside HIT [190, 191] and its role and application in acute settings is warranted.

Removal of visual fixation is important during a vestibular assessment [206] and is currently achieved with expensive video Frenzel equipment, such as used in this thesis. Easy access to a simple, inexpensive and portable video Frenzel device or an equivalent would be an appropriate next step in technological advances to impact vestibular assessment and management in ED / AME [105].

Incorporating VST into a clinical referral guide in ED / AME

It would be appropriate for the VST to sit within a clinical referral guide for use in ED / AME to determine how to manage people presenting to hospital with dizziness, including people with a potential emergent disorder such as a posterior circulation stroke. A clinical referral guide has been developed following the outcomes of this thesis, to assist ED / AME clinicians' decision making in regards to referral pathways of people presenting to hospital with dizziness and / or vertigo (see Appendix F).

The VST is included in the flow diagram as one of several steps to the referral guide. Neurologists, ear nose throat specialists, stroke physicians and ED medical officers, along with vestibular physiotherapists, developed the referral guide. The findings from this research regarding the validation of the VST, clinical effectiveness of physiotherapy services in the hospital setting and appropriate intervention pathways, contributed to the development of the referral guide. Validation of this guide would be an appropriate next step with potential for future application internationally.

6.4.3 Prevalence of vestibular disorders in ED / AME

Prevalence of specific vestibular disorders presenting to ED / AME is a future research area. As outlined in Section 2.2.4, while the prevalence of vestibular disorders in ED has been examined to some extent, there is a lack of prevalence studies reporting specific vestibular disorder prevalence in ED such as BPPV compared to vestibular migraine.

In the VST initial validation studies, BPPV accounted for 53% of the vestibular diagnoses, whilst vestibular migraine was potentially under-represented with only 3.6% of the vestibular diagnoses (see Section 5.2.4). Vestibular migraine has been described as the second most prevalent vestibular disorder in the community setting [49] and at least 10% of people in out-patient dizziness clinics have vestibular migraine [52]. Further prevalence studies in ED / AME are warranted.

6.4.4 Potential applications of the physiotherapy-led vestibular model of care

A number of future applications of the physiotherapy-led vestibular model of care could be explored, both clinically and from a research perspective.

Specialist wait-lists

Physiotherapy vestibular services could be beneficial for assisting people with dizziness who are on specialist waitlists, such as ear, nose, throat specialty, neurology and general medicine waitlists [440, 441]. It is hypothesised that a proportion of people who present to hospital with dizziness, are referred to see a specialist without being referred to vestibular physiotherapy alternatively or as an addition to the specialist referral [440, 441]. Therefore, specialist waitlists may include people that could be effectively managed through a vestibular physiotherapy service instead of the specialist or in addition to seeing the specialist. It is important that people are referred appropriately for vestibular physiotherapy to prevent unwarranted specialist referrals occurring which may extend specialist wait-lists.

Acute versus chronic vestibular disorder presentation and outcomes

Future studies could investigate the clinical presentation and outcomes of people with an acute vestibular disorder, compared to those with chronic vestibular disorders. Determining clinical outcomes based on time from onset of symptoms and time to receive treatment would be of value. Such a study could be carried out

by comparing those on a specialist waitlist (for example an ear, nose throat specialist waitlist) with those who present to hospital with an acute, first episode of dizziness / vertigo. It is hypothesised that people with acute dysfunction would be less likely to develop secondary disorders, and would therefore require less intervention to achieve resolution / reduction of symptoms. Additionally, it is hypothesised that patient satisfaction would likely be higher in the acute group, and may require less health care utilisation than those with chronic symptoms related to a vestibular disorder. The results may lend additional support for the importance of early intervention of vestibular disorders.

Multi-site study of clinical effectiveness of vestibular model of care

It is recommended that a multi-site study be undertaken to further test the proposed physiotherapy vestibular model of care. A multi-site study would test the hypothesis that the physiotherapy vestibular model of care is clinically effective and a cost-effective strategy in managing people who present to hospital with non-emergent vestibular disorders.

There is potential for such a multi-site study to be conducted within Queensland. As a result of the outcomes of this research, the Queensland vestibular collaborative has been established. The Queensland vestibular collaborative involves several hospitals in Queensland who are establishing vestibular models of care within their service. The primary aim of the collaborative is to assist in the rollout of similar

models of care as developed in this thesis, across Queensland Health hospitals. This is potentially an important platform for future research involving multiple hospitals across Queensland. Several hospitals are currently seeking funding for the establishment of and / or implementing the physiotherapy vestibular model of care. Data collection on the outcomes and effectiveness of these newly established services is occurring throughout these hospitals. Ensuring a minimum dataset these services may assist in investigating the clinical and cost-effectiveness of physiotherapy vestibular services in hospital settings within a multi-site study.

6.5 Conclusion

The broad aim of this thesis was to improve the service model of care (screening and management) for people presenting to hospital with a non-emergent vestibular disorder. The results from this thesis, including the construction and validation of a new VST, and evidence to support effectiveness of a physiotherapy vestibular service in the hospital setting, show how this aim has been achieved. This thesis provides emerging research into vestibular physiotherapy in the hospital setting, in particular in the ED. The clinical implications of implementing a physiotherapy-led vestibular model of care in the hospital setting may have significant positive benefits to individuals, including improved access to appropriate management, and may prove to reduce burden on hospitals and society. This research has demonstrated effectiveness of the physiotherapists working with advanced

vestibular skill in ED / AME. It signals a role for the specialist physiotherapist working in conjunction with medical officers in differentiating emergent and non-emergent vestibular disorders in ED / AME. Future directions for research include cost-effectiveness of vestibular physiotherapy in the hospital setting and further investigation of vestibular physiotherapist's role in ED / AME.

Chapter 7 References

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Chapter 8 Appendices

Appendix A. Approval to use COSMIN table in thesis

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Appendix B. Search criteria / terms for systematic review (Paper 1)

Search Criteria / terms: CINAHL (Ebsco)

Vestibular dysfunction diagnosis / Symptoms of dizziness / vertigo:

1. (MH "Vestibular Diseases+DI/RH") OR AB Vestibular
2. (MH "Vertigo+DI/RH")
3. (MH "Dizziness/DI/RH")
4. AB Vertigo or vestibulopath* or dizziness or ((vestibular or balance*) and (disorder or hypofunction* or dysfunction* or impair* or disability* or pathology* or disturbance*))
5. (MH "Labyrinth Diseases+ DI/RH")
6. (MH "VESTIBULOCOCHLEAR NERVE DISEASES+")
7. AB NEUROLABYRINTHITIDES or NEUROLABYRINTHITIS or (VESTIBULAR and (NEUVestibular RITIS or NEURONITIS or NEURITIDES))
8. AB (ACOUSTIC adjNEUROMA) or (ACOUSTIC adj NEURINOMA) or (ACOUSTIC adjNEURILEMOMA) or (ACOUSTIC adj NEURILEMMOMA) or (VESTIBULARadj SCHWANNOMA) or (ACOUSTIC adj SCHWANNOMA) or (MOTION adj SENSITIVITY) or (VESTIBULAR and PERIPHERAL) or (PERILYMPHATIC and FISTULA) or MENIERE* or (ENDOLYMPHATIC and HYDROPS) or (LABYRINTH* and HYDROPS) or (LABYRINTH* and SYNDROME) or BPV or BPPV or ANTBPPV
9. #1 OR #2 OR 3 OR #4 OR #5 OR #6 OR #7 OR # 8

Vestibular Rehabilitation:

10. AB vestibular and AB (REHABILITATION or ADAPTATION or HABITUATION)
11. (MH“Occupational Therapy+”)
12. (MH“PhysicalTherapy+”)
13. (MH “Exercise+”)
14. (MH “Vestibular Function Tests+”)
15. AB REHABILITATION or PHYSIOTHERAP* or (PHYSICAL and THERAP*) or EXERCIS* or HABITUAT* or EPLEY or CANALITH or SEMONT or MANOEUVRE* or MANEUVER* or (RECONDITIONING adj ACTIVIT*) or POSTUROGRAPHY or (POSTURAL adj CONTROL) or PFPP or (SENSORY and RELEARN) or (SENSORY and RETRAIN*) or (POSTURAL and RELEARN*) or (POSTURAL and RETRAIN*)
16. AB (POSITION* and PROCEDURE*) or (REPOSI TION* and PROCEDURE*) or (REPOSITION* and PARTICLE*) or (VISUAL and VESTIBULAR) or (FUNCTIONAL and RETRAIN*) or (OCCUPATIONAL and RETRAIN*) or (OCCUPATIONAL and ADAPTATION) or (COOKSEY and CAWTHORNE)
17. #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16
18. #4 AND #17
19. #9 OR #18

DOMAIN:

20. MH “Vertigo” OR MH “Dizziness” OR AB Vertigo Or AB Dizziness

OUTCOME:

21. (MH "Outcome Assessment")
22. (MH "Questionnaires+")
23. AB (MH "Questionnaires+")
24. Questionnaire* OR interview* OR self-report* OR measure* OR instrument* OR scale* OR tool*
25. #21 OR #22 OR #23 OR 24
26. #19 and #20 AND #25

Search Criteria / terms: EMBASE

Vestibular dysfunction diagnosis /Symptoms of dizziness / vertigo:

1. exp vestibular disorder/di, rh [Diagnosis, Rehabilitation]
2. exp vertigo/di, rh [Diagnosis, Rehabilitation]
3. dizziness/di, rh [Diagnosis, Rehabilitation]
4. (VESTIBULAR and (REHABILITATION or ADAPTATION or HABITUATION)).Ti.
5. Vestibular.ti,ab.
6. exp *inner ear disease/
7. perilymph/and fistula/

8. (Vertigo or vestibulopath* or dizziness or ((vestibular or balance*) and (disorder or hypofunction* or dysfunction* or impair* or disability* or pathology* or disturbance*))).ti,ab.
9. (NEUROLABYRINTHITIDES or NEUROLABYRINTHITIS or (VESTIBULAR and (NEURITIS or NEURONITIS or NEURITIDES))).ti,ab.
10. ((ACOUSTIC EXadj NEUROMA) or (ACOUSTIC adj NEURINOMA) or (ACOUSTIC adj NEURILEMOMA) or (ACOUSTIC adj NEURILEMMOMA) or (VESTIBULAR adj SCHWANNOMA) or (ACOUSTIC adj SCHWANNOMA) or (MOTION adj SENSITIVITY) or (VESTIBULAR and PERIPHERAL) or (PERILYMPHATIC and FISTULA) or MENIERE* or (ENDOLYMPHATIC and HYDROPS) or (LABYRINTH* and HYDROPS) or (LABYRINTH* and SYNDROME) or BPV or BPPV or ANTBPPV).ti,ab.
11. 6 OR 7 OR 8 OR 9 OR 10

12. VOCATIONAL REHABILITATION/or exp KINESIOTHERAPY/or exp EXERCISE/or exp HEAD MOVEMENT/
13. (REHABILITATION or PHYSIOTHERAP* or (PHYSICAL and THERAP*) or EXERCIS* or HABITUAT* or EPLEY or CANALITH or SEMONT or MANOEUVRE* or MANEUVER* or (RECONDITIONING adj ACTIVIT*) or POSTUROGRAPHY or (POSTURAL adj CONTROL) or PFPP or (SENSORY and

RELEARN) or (SENSORY and RETRAIN*) or (POSTURAL and RELEARN*) or (POSTURAL and RETRAIN*)).Ti,ab.

14. ((POSITION* and PROCEDURE*) or (REPOSITION* and PROCEDURE*) or (REPOSITION* and PARTICLE*) or (VISUAL and VESTIBULAR) or (FUNCTIONAL and RETRAIN*) or (OCCUPATIONAL and RETRAIN*) or (OCCUPATIONAL and ADAPTATION) or (COOKSEY and CAWTHORNE)).Ti,ab.
15. 12 OR 13 OR 14
16. 11 AND 15
17. 1 OR 2 OR 3 OR 4 OR 5 OR 16

OUTCOME:

18. exp *Outcome assessment/OR exp *Questionnaire/
19. (Questionnaire* OR interview* OR self-report* OR measure* OR instrument* OR scale* OR tool*).ti,ab.
20. 18 OR 19
21. 17 AND 20

Search Criteria / terms: PUBMED

PATIENT: (set as adult)

Vestibular dysfunction diagnosis /Symptoms of dizziness / vertigo:

1. Vestibular diseases [Mesh] OR Vertigo [Mesh] OR Dizziness [Mesh] OR Vestibular (tiab)

2. Vertigo [tiab] OR vestibulopath*[tiab] OR dizziness [tiab] OR ((vestibular[ti] OR balance* [ti]) AND (disor-HYder[ti] OR hypofunction* [ti] OR dysfunction* [ti] OR impair* [ti] OR disability* [ti] OR pathology* [ti] OR disturbance* [ti]))
3. Labyrinth diseases (Mesh) OR Vestibulocochlear nerve diseases (Mesh) OR Perilymph (Mesh) AND Fistulo (Mesh)
4. NEUROLABYRINTHITIDES [tiab] OR NEUROLABYRINTHITIS [tiab] OR (VESTIBULAR [tiab] AND (NEURITIS [tiab] OR NEURONITIS [tiab] OR NEURITIDES[tiab]))
5. "VESTIBULAR NERVE" [tiab] AND (INFLAMMATION [tiab] OR COMPRESSION [tiab]))
6. "ACOUSTIC NEUROMA" [tiab] OR "ACOUSTIC NEURINOMA" [tiab] OR "ACOUSTIC NEURILEMOMA" [tiab] OR "ACOUSTIC NEURILEMMOMA" [tiab] OR "VESTIBULAR SCHWANNOMA" [tiab] OR "ACOUSTIC SCHWANNOMA" [tiab] OR "MOTION SENSITIVITY" [tiab] OR (VESTIBULAR [tiab] AND PERIPHERAL [tiab]) OR (PERILYMPHATIC [tiab] AND FISTULA [tiab]) OR MENIERE* [tiab] OR "ENDOLYMPHATIC HYDROPS" [tiab] OR (LABYRINTH* [tiab] AND HYDROPS [tiab]) OR (LABYRINTH* [tiab] AND SYNDROME [tiab]) OR BPV [tiab] OR BPPV [tiab] OR ANTBPPV [tiab]
7. #2 OR #3 OR #4 OR #5 OR #6

Vestibular Rehabilitation:

8. (VESTIBULAR [tiab] AND (REHABILITATION [tiab] OR ADAPTATION [tiab] OR HABITUATION [tiab]))
9. "OCCUPATIONAL THERAPY" [Mesh] OR "PHYSICAL THERAPY MODALITIES" [Mesh] OR "EXERCISE THERAPY" [Mesh] OR "EXadjERCISE" [Mesh] OR "HEAD MOVEMENTS" [Mesh] OR "VESTIBULAR FUNCTION TESTS" [Mesh]
10. REHABILITATION [tiab] OR PHYSIOTHERAP* [tiab] OR (PHYSICAL [tiab] AND THERAP* [tiab]) OR EXERCIS* [tiab] OR HABITUAT* [tiab] OR EPLEY [tiab] OR CANALITH [tiab] OR SEMONT [tiab] OR MANOEUVRE* [tiab] OR MANEUVER* [tiab] OR "RECONDITIONING ACTIVIT*" [tiab] OR POSTUROGRAPHY [tiab] OR "POSTURAL CONTROL" [tiab] OR PFPP [tiab] OR (SENSORY [tiab] ANDRELEARN* [tiab]) OR (SENSORY [tiab] AND RETRAIN* [tiab]) OR (POSTURAL [tiab] AND RELEARN* [tiab]) OR (POSTURAL [tiab] AND RETRAIN* [tiab])
11. (POSITION* [tiab] AND PROCEDURE* [tiab])OR (REPOSITION* [tiab] AND PROCEDURE* [tiab])OR(REPOSITION* [tiab] AND PARTICLE* [tiab]) OR (VISUAL [tiab] AND VESTIBULAR [tiab]) OR (FUNCTIONAL [tiab] ANDRETRAIN* [tiab]) OR (OCCUPATIONAL [tiab] ANDRETRAIN* [tiab]) OR (OCCUPATIONAL [tiab] AND ADAPTATION [tiab]) OR (COOKSEY [tiab] AND CAWTHORNE [tiab])
12. #8 OR #9 OR #10 OR #11
13. #2 AND #12

14. #1 OR #7 OR #13

DOMAIN: identify and quantify symptoms associated with vestibular dysfunction: dizziness / vertigo, imbalance and gait disturbance, quality of life.

15. Vertigo [Mesh] OR Dizziness [Mesh] OR Vertigo [tiab] OR dizziness [tiab]

OUTCOME:

16. Outcome assessment (health care) (MESH) OR Questionnaires (MESH)
17. Questionnaire* (tiab) OR interview* (tiab) OR self-report* (tiab) OR measure*(tiab) OR instrument* (tiab) OR scale* (tiab) OR tool* (tiab)
18. #16 OR #17
19. #14 AND #15 AND #18

CLINIMETRIC PROPERTIES:

20. Outcomes or Psychometrics

<u>Search criteria / terms Web of Science</u>

1. TI=(Vertigo or vestibulopath* or dizziness or ((vestibular or balance*) and (disorder or hypofunction* or dysfunction* or impair* or disability* or pathology* or disturbance*)))
2. TI=(NEUROLABYRINTHITIDES or NEUROLABYRINTHITIS or (VESTIBULAR and (NEURITIS or NEURONITIS or NEURITIDES)))
3. TI=((ACOUSTIC adj NEUROMA) or (ACOUSTIC adj NEURINOMA) or (ACOUSTIC adj NEURILEMOMA) or (ACOUSTIC adj NEURILEMMOMA) or (VESTIBULAR adj SCHWANNOMA) or (ACOUSTIC adj SCHWANNOMA) or

(MOTION adj SENSITIVITY) or (VESTIBULAR and PERIPHERAL) or (PERILYMPHATIC and FISTULA) or MENIERE* or (ENDOLYMPHATIC and HYDROPS) or (LABYRINTH* and HYDROPS) or (LABYRINTH* and SYNDROME) or BPV or BPPV or ANTBPPV or "benign paroxysmal positional vertigo")

4. #1 OR #2 OR #3
5. TS=(VESTIBULAR and (REHABILITATION or ADAPTATION or HABITUATION))
6. TS=(REHABILITATION or PHYSIOTHERAP* or (PHYSICAL and THERAP*) or EXERCIS* or HABITUAT* or EPLEY or CANALITH or SEMONT or MANOEUVRE* or MANEUVER*

- or (RECONDITIONING adj ACTIVIT*) or POSTUROGRAPHY or (POSTURAL adj CONTROL) or PFPP or (SENSORY and RELEARN) or (SENSORY and RETRAIN*) or (POSTURAL and RELEARN*) or (POSTURAL and RETRAIN*))

7. TS=((POSITION* and PROCEDURE*) or (REPOSITION* and PROCEDURE*) or (REPOSITION* and PARTICLE*) or (VISUAL and VESTIBULAR) or (FUNCTIONAL and RETRAIN*) or (OCCUPATIONAL and RETRAIN*) or (OCCUPATIONAL and ADAPTATION) or (COOKSEY and CAWTHORNE))
8. #5 OR #6 OR #7
9. #8 AND #1
10. #2 OR #9

11. TI=(Questionnaire* OR interview* OR self-report* OR measure* OR instrument* OR scale* OR tool*)
12. #10 AND #11

Appendix C. COSMIN item scoring for systematic review (Paper 1)

COSMIN item scoring for content validity (including face validity)

Measure	Study	Overall	1.Items relevant to the construct?	2. Items relevant to study population?	3. Items relevant for the purpose of the study?	4. All items together reflect construct?	5. Important flaws in methods?
Dizziness Handicap Inventory	Jacobson and Newman, 1990	Excellent (+++)	Yes	Yes	Yes	Yes	No
Vertigo symptom scale	Yardley, 1992a	Fair (+)	Yes	No	No	Yes	No
Vestibular Activities and Participation measure	Alghwiri, 2012	Excellent (+++)	Yes	Yes	Yes	Yes	No
Vestibular Rehabilitation Benefit Questionnaire	Morris, 2008	Excellent (+++)	Yes	Yes	Yes	Yes	No
Visual vertigo analogue	Dannenbaum,	ND					

scale	2011						
Vertigo Handicap Questionnaire	Yardley, 1992b	Excellent (+++)	Yes	Yes	Yes	Yes	No
Vertigo, Dizziness, Imbalance questionnaire	Prieto, 1999	Excellent (+++)	Yes	Yes	Yes	Yes	No
Vestibular disorders Activities of Daily Living	Cohen, 2000a	Excellent (+++)	Yes	Yes	Yes	Yes	No
Dizziness Handicap Inventory Screening	Jacobson, 1998	ND					

Key: ND: No Data, N/A: Not Applicable.

COSMIN Item Scoring for Criterion Validity

Measure	Study	Overall	1. Percentage of Missing items given?	2. Missing item handling	3. Sample size	4. Used 'gold standard'	5. Flaws in design or method	6. Continuous: correlation or ROC curve	7. Dichotomous: Sensitivity or specificity
Dizziness Handicap Inventory	Jacobson and Newman, 1990	Poor (0)	No	No	No	Yes	Yes	Yes	N/A
Vertigo symptom scale	Yardley, 1992a	Good (++)	Yes	No	Yes	Yes	No	Yes	N/A
Vestibular Activities and Participation measure	Alghwiri, 2012	Fair (+)	No	No	Yes	Yes	No	Yes	N/A
Vestibular Rehabilitation Benefit Questionnaire	Morris, 2009	Excellent (+++)	Yes	Yes	Yes	Yes	No	Yes	N/A

Visual vertigo analogue scale	Dannenbaum, 2011	Good (++)	No	No	Yes	Yes	No	Yes	N/A
Vertigo Handicap Questionnaire	Yardley, 1992b	ND							
Vertigo, Dizziness, Imbalance questionnaire	Prieto, 1999	Poor (0)	No	No	Yes	No	No	Yes	N/A
Vestibular disorders Activities of Daily Living	Cohen, 2000	ND							
Dizziness Handicap Inventory Screening	Jacobson, 1998	Fair (+)	No	No	Yes	Yes	No	Yes	N/A

Key: ND: No Data, N/A: Not Applicable.

COSMIN Item Scoring for Internal Consistency

Measure	Study	Overall	1	2	3	4	5	6	7	8	9	10	11
Dizziness Handicap Inventory	Jacobson and Newman, 1990	Fair (+)	?	No	No	Yes	No	?	Yes	No	Yes	N/A	N/A
Vertigo symptom scale	Yardley, 1992a	Good (++)	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	N/A	N/A
Vestibular Activities and Participation measure	Alghwiri, 2012	ND											
Vestibular Rehabilitation Benefit Questionnaire	Morris, 2009	Excellent (+++)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	N/A	N/A
Visual vertigo analogue scale	Dannenbaum, 2011	Poor (0)	?	No	No	Yes	No	Yes	Yes	Yes	Yes	N/A	N/A
Vertigo Handicap Questionnaire	Yardley, 1992b	Good (++)	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	N/A	N/A
Vertigo, Dizziness, Imbalance questionnaire	Prieto, 1999	Fair (+)	Yes	No	No	?	Yes	?	Yes	No	Yes	N/A	N/A

Vestibular disorders Activities of Daily Living	Cohen, 2000	Poor (0)	Yes	No	No	No	Yes	?	Yes	Yes	Yes	N/A	N/A
Dizziness Handicap Inventory Screening	Jacobson, 1998	ND											

Key: No Data, N/A: Not Applicable, 1. Scale consist of effect indicators? 2. Percentage of missing items given? 3. Missing items handled? 4. Sample size? 5. Unidimensionality? 6. Sample size for unidimensionality? 7. Statistic for each (sub)scale separately? 8.Important flaws in design or method? 9. Chronbach alpha for Classcical test theory? 10. Chonbach alpha or KR-20 calculated for dichotomous scores? 11. Goodness of fit statistic for IRT?

COSMIN Item Scoring for Reliability (Inter-rater and intra-rater)

Measure	Study	Overall	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Dizziness Handicap Inventory	Jacobson and Newman, 1990	ND														
Vertigo symptom scale	Yardley, 1992a	ND														
Vestibular Activities and Participation measure	Alghwiri, 2012	ND														
Vestibular Rehabilitation Benefit Questionnaire	Morris, 2009	ND														
Visual vertigo analogue scale	Dannenbaum, 2011	ND														
Vertigo Handicap Questionnaire	Yardley, 1992b	ND														

Vertigo, Dizziness, Imbalance questionnaire	Prieto, 1999	ND
Vestibular disorders Activities of Daily Living	Cohen, 2000	ND
Dizziness Handicap Inventory Screening	Jacobson, 1998	ND

Key: ND: No Data, N/A: Not Applicable, ?: unknown. 1. Percentage of missing items given? 2. Missing items handling? 3. Sample size? 4. Atleast 2 measurements? 5. Administrations independently? 6. Time interval stated? 7. Patients stable in interim period? 8. Time interval appropriate? 9. Test conditions similar for both measurements? 10. Important flaws in design / methods? 11. Continuous: ICC? 12. Dichotomous / nominal / ordinal scores: Sensitivity or specificity? 13. Ordinal: Kappa 14. Ordinal: weighted scheme?

COSMIN Item Scoring for Reliability (Test-retest)

Measure	Study	Overall	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Dizziness Handicap Inventory	Jacobson and Newman, 1990	Poor (0)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A
Vertigo symptom scale	Yardley, 1992a	Good (++)	Yes	No	Yes	Yes	Yes	Yes	?	Yes	Yes	No	Yes	N/A	N/A	N/A
Vestibular Activities and Participation measure	Alghwiri, 2012	Good (++)	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	N/A	N/A	N/A
Vestibular Rehabilitation Benefit Questionnaire	Morris, 2009	Good (++)	Yes	Yes	Yes	Yes	Yes	Yes	?	Yes	?	No	Yes	N/A	N/A	N/A
Visual vertigo analogue scale	Dannenbaum, 2011	ND														
Vertigo Handicap Questionnaire	Yardley, 1992b	ND														

Vertigo, Dizziness, Imbalance questionnaire	Prieto, 1999	Fair (+)	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	N/A	N/A	N/A
Vestibular disorders Activities of Daily Living	Cohen, 2000	Poor (0)	No	No	No	Yes	Yes	Yes	?	Yes	Yes	Yes	No	N/A	N/A	N/A
Dizziness Handicap Inventory Screening	Jacobson, 1998	Poor (0)	No	No	No	Yes	Yes	Yes	?	Yes	No	Yes	Yes	N/A	N/A	N/A

Key: ND: No Data, N/A: Not Applicable, ?: unknown. 1. Percentage of missing items given? 2. Missing items handling? 3. Sample size? 4. Atleast 2 measurements? 5. Administrations independently? 6. Time interval stated? 7. Patients stable in interim period? 8. Time interval appropriate? 9. Test conditions similar for both measurements? 10. Important flaws in design/methods? 11. Continuous: ICC? 12. Dichotomous / nominal / ordinal scores: Sensitivity or specificity? 13. Ordinal: Kappa 14. Ordinal: weighted scheme?

COSMIN Item Scoring for Responsiveness

Measure	Study	Overall	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Dizziness Handicap Inventory	Jacobson and Newman, 1990	ND																		
Vertigo symptom scale	Yardley, 1992a	ND																		
Vestibular Activities and Participation measure	Alghwiri, 2012	ND																		
Vestibular Rehabilitation Benefit Questionnaire	Morris, 2009	Poor (0)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	Yes	No	Yes	Yes	No	N/A
Visual vertigo analogue scale	Dannenbaum, 2011	ND																		

Vertigo Handicap Questionnaire	Yardley, 1992b	Poor (0)	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No	No	No	Yes	No	N/A	Yes	No	N/A
Vertigo, Dizziness, Imbalance questionnaire	Prieto, 1999	Poor (0)	No	No	Yes	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	N/A	Yes	No	N/A
Vestibular disorders Activities of Daily Living	Cohen, 2000	ND																		
Dizziness Handicap Inventory Screening	Jacobson, 1998	ND																		

Key: ND: No Data, N/A: Not Applicable. 1. Percentage of missing items given? 2. Missing items handling? 3. Sample size adequate? 4. Longitudinal design? 5. Time interval stated? 6. Intervention adequately described? 7. Change in patients? 8. Hypothesis formulated? 9. Expected correlations included in hypothesis? 10. Magnitude of correlations included in hypotheses? 11. Comparator instruments description? 12. Measurement properties of comparator instruments? 13. Flaws in design? 14. Statistical methods adequate? 15. Gold standard criterion for change? 16. Flaws in study design? 17. Continuous correlations or ROC calculated? 18. Dichotomous: sensitivity / specificity determined?

Appendix D. Approval to use published manuscripts (Paper 2)

License number	Reference confirmation email for license number
License date	Mar, 06 2017
Licensed Content Publisher	Elsevier
Licensed Content Publication	Archives of Physical Medicine and Rehabilitation
Licensed Content Title	Construction and Validation of the Vestibular Screening Tool for Use in the Emergency Department and Acute Hospital Setting
Licensed Content Author	Vicky Stewart,M. Dilani Mendis,Jeffrey Rowland,Nancy Low Choy
Licensed Content Date	December 2015
Licensed Content Volume	96
Licensed Content Issue	12
Licensed Content Pages	8
Type of Use	reuse in a thesis/dissertation
Portion	full article
Format	both print and electronic
Are you the author of this Elsevier article?	Yes
Will you be translating?	No
Order reference number	
Title of your thesis/dissertation	Improving screening, referral and physiotherapy service of vestibular disorders in the hospital setting
Expected completion date	May 2017
Estimated size (number of pages)	320
Elsevier VAT number	GB 494 6272 12
Requestor Location	Vicky M Stewart 3 Burnham St

Appendix E. COSMIN item and overall scoring for the Vestibular Screening Tool

COSMIN Measurement Property	COSMIN Item	Paper 2: Construction and validation of the Vestibular Screening Tool	Paper 3: Concurrent validity and responsiveness to change of the Vestibular Screening Tool	Overall Score
Content validity (including face validity)	1.Items relevant to the construct?	Yes	ND	Excellent (+++)
	2. Items relevant to study population?	Yes	ND	
	3. Items relevant for the purpose of the study?	Yes	ND	
	4. All items together reflect construct?	Yes	ND	
	5. Important flaws in methods?	No	ND	
Criterion Validity	1. Percentage of Missing items given?	ND	No	Fair (+)
	2. Missing item handling	ND	No	
	3. Sample size	ND	Yes	
	4. Used 'gold standard'	ND	Yes	
	5. Flaws in design or method	ND	No	

	6. Continuous: correlations or ROC curve	ND	Yes	
	7. Dichotomous: Sensitivity or specificity	ND	N/A	
Internal Consistency	1. Scale consists of effect indicators?	Yes	ND	Good (++)
	2. Percentage of missing items given?	No	ND	
	3. Description of how missing items handled?	No	ND	
	4. Sample size included?	Yes	ND	
	5. Was unidimensionality checked?	Yes	ND	
	6. Sample size included in unidimensionality analysis?	Yes	ND	
	7. Statistic calculated for each sub-scale?	Yes	ND	
	8. Important flaws in design or methods?	No	ND	
	9. Classic Test Theory: Cronbach's alpha calculated?	N/A	ND	
	10. Dichotomous: Cronbach's Alpha or KR-20?	N/A	ND	
	11. Item Response Theory: Goodness to fit statistic calculated?	Yes	ND	

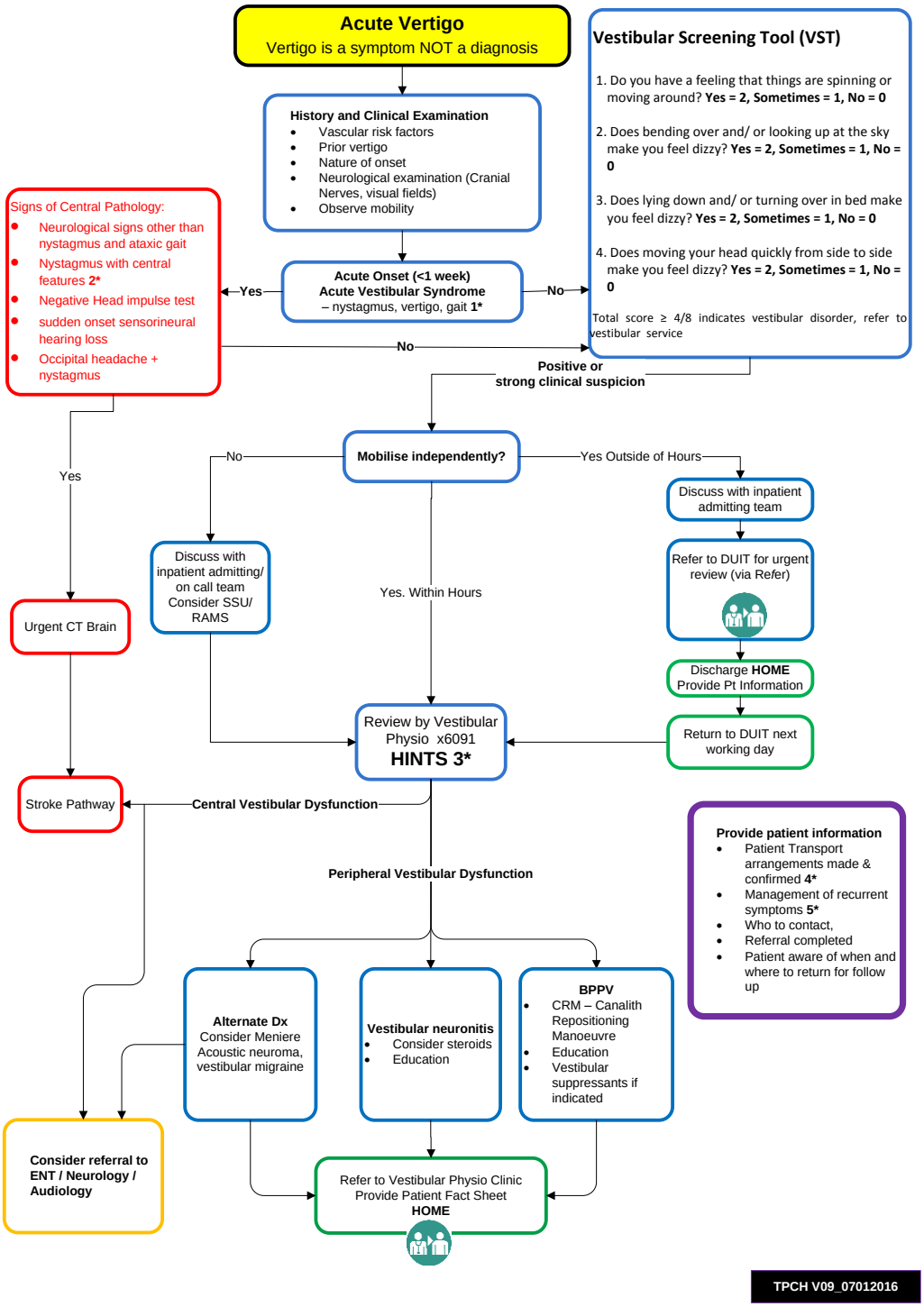
Reliability (Inter-rater and intra-rater)	1. Percentage of missing items given?	No	ND	Fair (+)
	2. Description of how missing items handled?	No	ND	
	3. Sample size included?	Yes	ND	
	4. Atleast 2 measurements available?	Yes	ND	
	5. Administrations independent?	Yes	ND	
	6. Time interval stated?	Yes	ND	
	7. Patients stable in the interim period?	?	ND	
	8. Time interval appropriate?	?	ND	
	9. Test conditions similar for both measurements?	Yes	ND	
	10. Important flaws in design or methods?	No	ND	
	11. continuous scores: Intraclass correlations calculated?	Yes	ND	
	12. Dichotomous / nominal / ordinal scores: Kappa calculated?	N/A	ND	
	13. Ordinal scores: Weighted Kappa calculated?	N/A	ND	
	14. Ordinal scores: weighting scheme described?	N/A	ND	
Responsiveness	1. Percentage of missing items given?	ND	No	Good (++)

	2. Description of how missing items handled?	ND	No
	3. Sample size included?	ND	Yes
	4. Longitudinal design with atleast 2 measurements used?	ND	Yes
	5. Time interval stated?	ND	Yes
	6. Intervention adequately described?	ND	Yes
	7. Was a proportion of patients changed?	ND	Yes
	8. Hypotheses about changes in scores formulated?	ND	Yes
	9. Direction of correlations included in hypotheses?	ND	Yes
	10. Expected magnitude of correlations or mean differences of change scores included in hypotheses?	ND	Yes
	11. Adequate description provided of comparator instrument?	ND	Yes
	12. Were measurement properties of comparator instrument described?	ND	Yes
	13. Important flaws in design or methods?	ND	Yes

	14. Design and statistical methods adequate?	ND	Yes
	15. Criterion for change be considered as a reasonable gold standard?	ND	Yes
	16. Important flaws in design or methods of study using gold standard.	ND	No
	17. Continuous scores: Correlations between change scores or area under the curve calculated?	ND	Yes
	18. Dichotomous: sensitivity and specificity determined?	ND	N/A

Abbreviations: COSMIN, consensus-based Standards for the selection of health measurement instruments; ND: no data; N/A, not applicable

Appendix F. Flow diagram of referral guide utilising VST



Appendix G. Publications list

Published / accepted papers

1. Stewart, V., Mendis, M.D., Low Choy, N. *A systematic review of patient-reported measures associated with vestibular dysfunction*. Laryngoscope, 2018. **128**: p. 971-981.
2. Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. *Construction and Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting.* Archives of Physical Medicine and Rehabilitation, 2015. **96**: p. 1253-1260.
3. Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. Concurrent validity and responsiveness to change of the Vestibular Screening Tool, to screen for vestibular disorders in the acute hospital setting. Otorinolaringologia, 2018. Manuscript in press.

Submitted papers

- Stewart, V., Mendis, M.D., Low Choy, N. Clinical effectiveness of a physiotherapy-led vestibular service in a tertiary hospital comparing immediate and delayed intervention pathways. Laryngoscope, 2017. Manuscript submitted for publication.

Appendix H. Proof of publications

Paper 1

Dear Vicky Stewart,

Article ID: LARY26641
Article DOI: 10.1002/lary.26641
Internal Article ID: 14129579
Article: A systematic review of patient-reported measures associated with vestibular dysfunction
Journal: The Laryngoscope

Congratulations on the acceptance of your article for publication in The Laryngoscope.
Your article has been received by production. You may wish to access Wiley Author Services to view your article record. Please click here or paste this link into your browser to register for Wiley Author Services.
http://authorservices.wiley.com/index.html#register-invite/CPGVHvSpDlAAQEspA2qoUs2S4EIbKstvd6SzR48nI9g=
Track your article's progress to publication
Access your published article
Invite colleagues to view your published article

Sincerely,
Wiley Author Services

Paper 2

Ms. Ref. No.: ARCHIVES-PMR-D-15-00606R2

Title: Construction and Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting

Archives of Physical Medicine and Rehabilitation

Dear Mrs. Stewart,

I am pleased to inform you that your manuscript, "Construction and Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting," has been accepted for publication in the Archives of Physical Medicine and Rehabilitation.

The accepted version of your manuscript will receive a final screen for completeness and compliance with Archives' guidelines before being released to the publisher for copyediting and typesetting. The accepted version of your article will then be posted online and placed in the PubMed database within approximately one week of release. Within about 6 weeks, this version will be replaced both online and in PubMed by the version of record (a copyedited and typeset version which is considered published, archival and fully citable).

If you do not want the accepted version of your article posted online, please respond to this email immediately. The copyedited and typeset version will still be published online in about 6 weeks.

The typeset proof of the copyedited manuscript will be delivered to your e-mail address in PDF format. You will be expected to approve your proof within 48 hours of receipt.

Reprint information will be sent to you directly by the publisher.
Sign up to receive Article in Press alerts (http://www.archives-pmr.org/user/addaipalerts) and know immediately when your article is published online. You can also track your article through the production process here: Elsevier's Online Author Communication System (OACS) (http://authors.elsevier.com/TrackPaper.html)
When your paper is published on ScienceDirect, you want to make sure it gets the attention it deserves. To help you get your message across, Elsevier has developed a new, free service called AudioSlides: brief, webcast-style presentations that are shown (publicly available) next to your published article. This format gives you the opportunity to explain your research in your own words and attract interest. You will receive an invitation email to create an AudioSlides presentation shortly. For more information and examples, please visit http://www.elsevier.com/audioslides.

Thank you for giving the Archives of Physical Medicine and Rehabilitation the opportunity to publish your contribution to the literature of rehabilitation research.

Sincerely yours,

Chih-Hung Chang, Ph.D. (Section Editor)

Archives of Physical Medicine and Rehabilitation

Paper 3

Dear Ms. Vicky Stewart,

I am pleased to inform you that your manuscript entitled

Concurrent validity and responsiveness to change of the vestibular screening tool

received by the editorial office of Otorinolaringologia and registered under no. Otorinolaringol-2164 has been accepted for publication as Original Article.

Before preparation of the proofs, the manuscript will undergo copy-editing to align it with the journal's editorial standards. You will be contacted by the editorial staff should any questions arise.

From now on, any request for substantial changes in content (changes of title and authorship, new results and corrected values, changes in figures and tables) will be subject to a completely new peer-review process.

Thank you for considering the journal Otorinolaringologia for publication of your paper.

Sincerely,

Prof. Alberto Oliaro
Managing Editor
Otorinolaringologia
.....
Edizioni Minerva Medica
Corso Bramante 83-85
10126 Torino, Italy

Appendix I. Statement of contribution of others

Statement of contribution of others for Paper 1

Statement from co-authors confirming authorship contribution of the PhD candidate

Stewart, V., Mendis, M.D., Low Choy, N. *A systematic review of patient-reported measures associated with vestibular dysfunction*. Laryngoscope, 2017. Manuscript submitted for publication.

Stewart (candidate) contributed to the conception and design of the above paper; undertook the collection, analysis and interpretation of data; and prepared the paper for publication.

I acknowledge that my contribution to the above paper is 70 percent

Vicky Stewart

Low Choy contributed to conception and design of the study, assisted with the admission of articles to the systematic review and the interpretation of data, and reviewed the manuscript.

I acknowledge that my contribution to the above paper is 20 percent

Professor Nancy Low Choy

Mendis contributed to conception and design of the study, assisted with interpretation of data and reviewed the manuscript.

I acknowledge that my contribution to the above paper is 10 percent

Dr. Dilani Mendis

Statement of contribution of others for Paper 2

Statement from co-authors confirming authorship contribution of the PhD candidate

Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. *Construction and Validation of the Vestibular Screening Tool for use in the Emergency Department and Acute Hospital Setting*. Archives of Physical Medicine and Rehabilitation, 2015. 96: p. 1253-1260.

Stewart (candidate) contributed to conception and design of the above study, performed participant recruitment, data collection and measurement, conducted analysis and interpretation of data and prepared the manuscript.
I acknowledge that my contribution to the above paper is 60 percent
Vicky Stewart _____

Low Choy contributed to the conception and design of the study, assisted with interpretation of data and reviewed the manuscript.
I acknowledge that my contribution to the above paper is 20 percent
Professor Nancy Low Choy _____

Mendis contributed to the conception and design of the study, assisted with interpretation of data and reviewed the manuscript.
I acknowledge that my contribution to the above paper is 10 percent
Dr. Dilani Mendis _____

Rowland contributed to conception and design of the study, and reviewed the manuscript.
I acknowledge that my contribution to the above paper is 10 percent
Dr. Jeffrey Rowland _____

Statement of contribution of others for Paper 3

Statement from co-authors confirming authorship contribution of the PhD candidate

Stewart, V., Mendis, M.D., Rowland, J., Low Choy, N. *Concurrent validity and responsiveness to change of the Vestibular Screening Tool, to screen for vestibular disorders in the acute hospital setting*. Journal of Vestibular Research, 2017. Manuscript submitted for publication

Stewart (candidate) contributed to conception and design of the above study, performed participant recruitment, data collection and measurement, conducted analysis and interpretation of data and prepared the manuscript.
I acknowledge that my contribution to the above paper is 60 percent
Vicky Stewart

Low Choy contributed to the conception and design of the study, assisted with interpretation of data and reviewed the manuscript.
I acknowledge that my contribution to the above paper is 20 percent
Professor Nancy Low Choy

Mendis contributed to the conception and design of the study, assisted with interpretation of data and reviewed the manuscript.
I acknowledge that my contribution to the above paper is 10 percent
Dr. Dilani Mendis

Rowland contributed to conception and design of the study, and reviewed the manuscript.
I acknowledge that my contribution to the above paper is 10 percent
Dr. Jeffrey Rowland

Statement of contribution of others for Paper 4

Statement from co-authors confirming authorship contribution of the PhD candidate

Stewart, V., Mendis, M.D., Low Choy, N. *Clinical effectiveness of a physiotherapy-led vestibular service in a tertiary hospital comparing immediate and delayed intervention pathways*. Archives of Physical Medicine and Rehabilitation, 2017. Manuscript submitted for publication

Stewart (candidate) contributed to the conception and design of the above paper; undertook the collection, analysis and interpretation of data; and prepared the paper for publication.

I acknowledge that my contribution to the above paper is 70 percent

Vicky Stewart

Low Choy contributed to conception and design of the study, assisted with interpretation of data and reviewed the manuscript.

I acknowledge that my contribution to the above paper is 20 percent

Professor Nancy Low Choy

Mendis contributed to conception and design of the study, assisted with interpretation of data and reviewed the manuscript.

I acknowledge that my contribution to the above paper is 10 percent

Dr. Dilani Mendis

Appendix J. Ethics approval and amendment

Queensland Government

8 April 2013

Enquiries to: R&ETPCH@health.qld.gov.au
Philip_Lee@health.qld.gov.au
Office Ph: (07) 3139 4198
(07) 3139 4500
Our Ref: PL/JL/Approval Amendments

Miss Vicky Woodhead
Physiotherapy Department
The Prince Charles Hospital

Human Research Ethics Committee
Metro North Hospital and Health Service
The Prince Charles Hospital
Administration Building, Lower Ground
Rode Road, Chermside QLD 4032

Dear Miss Woodhead,

Re: HREC/12/QPCH/293: Is the Short-Form Dizziness Handicap Inventory valid to use in the Emergency Department to facilitate referral to physiotherapy for vestibular problems or for older adults being discharged home following a fall?

I am pleased to advise that The Prince Charles Hospital Human Research Ethics Committee reviewed the amendments submitted and upon recommendation, the Chair has granted approval for the following:

- Participant Information Sheet & Consent Form – Version 3, dated 18 March 2013
- The Short Form Dizziness Questionnaire – Version 4. dated 8 April 2013
- Dizziness Handicap Inventory (DHI) – Version 3, dated 8 April 2013

This information will be tabled at the next HREC meeting held 11 April 2013, for noting.

Patient information collected and distributed as part of the previously approved research has been approved in accordance with Section 62 of the Health Services Act and the recent amendments to the Public Health Act Sections 282 and 284. Any change to the collection and or distribution will need to be reviewed by the HREC.

On behalf of the Human Research Ethics Committee, I would like to wish you every success with your research endeavour.

Yours truly,

Philip Lee, MBA (UQ); BAppSc (QUT); FRCNA; AFAIM
Executive Officer – Research, Ethics and Governance Unit
Email: Philip_Lee@health.qld.gov.au

Queensland Government

26 April 2013

Enquiries to: R&ETPCH@health.qld.gov.au
Philip_Lee@health.qld.gov.au
Office Ph: (07) 3139 4198
(07) 3139 4500
Our Ref: PL/JL/Approval Amendments

Miss Vicky Woodhead
Physiotherapy Department
The Prince Charles Hospital

Human Research Ethics Committee
Metro North Hospital and Health Service
The Prince Charles Hospital
Administration Building, Lower Ground
Rode Road, Chermside QLD 4032

Dear Miss Woodhead,

Re: HREC/12/QPCH/293: Is the Short-Form Dizziness Handicap Inventory valid to use in the Emergency Department to facilitate referral to physiotherapy for vestibular problems or for older adults being discharged home following a fall?

I am pleased to advise that The Prince Charles Hospital Human Research Ethics Committee reviewed the amendments submitted and upon recommendation, the Chair has granted approval for the following:

- Protocol – Version 3, dated 23 April 2013,
- PICF – Version 4, dated 24 April 2013,
- Fall Diary – Version 1, dated 24 April 2013,
- Staff Survey Questionnaire – Version 1, dated 25 April 2013,
- Subject Assessment – Version 4, dated 25 April 2013,
- Functional Gait Assessment (FGA)

This information will be tabled at the next HREC meeting held 9 May 2013, for noting.

Sites included under this approval are:

No.	Site
1	The Prince Charles Hospital

Patient information collected and distributed as part of the previously approved research has been approved in accordance with Section 62 of the Health Services Act and the recent amendments to the Public Health Act Sections 282 and 284. Any change to the collection and or distribution will need to be reviewed by the HREC.

On behalf of the Human Research Ethics Committee, I would like to wish you every success with your research endeavour.

Yours truly,

Philip Lee, MBA (UQ); BAppSc (QUT); FRCNA; AFAIM
Executive Officer – Research, Ethics and Governance Unit

Enquiries to: R&ETPCH@health.qld.gov.au
Office Ph: Philip_Lee@health.qld.gov.au
(07) 3139 4198
Our Ref: (07) 3139 4500
PL/JL/Approval Amendments

Queensland Government

28 July 2013

Human Research Ethics Committee
Metro North Hospital and Health Service
The Prince Charles Hospital
Administration Building, Lower Ground
Rode Road, Chermside QLD 4032

Miss Vicky Woodhead
Physiotherapy Department
The Prince Charles Hospital

Dear Miss Woodhead,

Re: HREC/12/QPCH/293: Is the Short-Form Dizziness Handicap Inventory valid to use in the Emergency Department to facilitate referral to physiotherapy for vestibular problems or for older adults being discharged home following a fall?

I am pleased to advise that The Prince Charles Hospital Human Research Ethics Committee reviewed the amendments submitted and upon recommendation, the Chair has granted approval for the following:

- Extension of data recruitment time period to July 2014
- Vestibular Rehabilitation Benefit Questionnaire (VRBQ)
- Vestibular Screening Tool (VST) – Version 1, dated 25 June 2013
- Protocol – Version 4, dated 25 June 2013
- Participant Information Sheet & Consent Form – Version 5, dated 25 June 2013
- Advertisement

This information will be tabled at the next HREC meeting held 11 July 2013, for noting.

Patient information collected and distributed as part of the previously approved research has been approved in accordance with Section 62 of the Health Services Act and the recent amendments to the Public Health Act Sections 282 and 284. Any change to the collection and or distribution will need to be reviewed by the HREC.

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007)* and the *CPMP/ICH Note for Guidance on Good Clinical Practice.* **Please be advised that in the instance of an investigator being a member of the HREC, they are absented from the decision making process relating to that study.**

On behalf of the Human Research Ethics Committee, I would like to wish you every success with your research endeavour.

Yours truly,

Philip Lee, MBA (UQ); BAppSc (QUT); FRCNA; AFAIM
Executive Officer – Research, Ethics and Governance Unit

Enquiries to: R&ETPCH@health.qld.gov.au
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PL/JL/Approval Amendments

Queensland Government

20 August 2013

Human Research Ethics Committee
Metro North Hospital and Health Service
The Prince Charles Hospital
Administration Building, Lower Ground
Rode Road, Chermside QLD 4032

Miss Vicky Woodhead
Physiotherapy Department
The Prince Charles Hospital

Dear Woodhead

Re: HREC/12/QPCH/293: Is the Short-Form Dizziness Handicap Inventory valid to use in the Emergency Department to facilitate referral to physiotherapy for vestibular problems or for older adults being discharged home following a fall?

I am pleased to advise that The Prince Charles Hospital Human Research Ethics Committee reviewed the amendments submitted and upon recommendation, the Chair has granted approval for the following:

- Vestibular Screening Tool [VST] v3, dated 14 August 2013; [Appendix 1];
- EMU Advertisement v1, dated 14 Aug 2013 [Appendix 2];
- Activities Specific Balance Confidence [ABC 6] Scale, Version 1, dated 14 August 2013; [Appendix 3]
- Clinical Frailty Scale, Dalehouse University, [Appendix 4];
- Protocol v5, dated 14 August 2013 [Appendix 5]
- Sticker for Medical Chart [Appendix 6]
- Physiotherapy Vestibular Assessment Form [Appendix 7]

This information was tabled and reviewed at the HREC meeting held 12 September 2013 for noting.

A copy of this approval must be submitted to the relevant Hospital & Health Service Research Governance Officer/s or Delegated Personnel, along with Site Specific documentation, for CEO or Delegate authorisation for each site.

Patient information collected and distributed as part of the previously approved research has been approved in accordance with Section 62 of the Health Services Act and the recent amendments to the Public Health Act Sections 282 and 284. Any change to the collection and or distribution will need to be reviewed by the HREC.

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007)* and the *CPMP/ICH Note for Guidance on Good Clinical Practice*. **Please be advised that in the instance of an investigator being a member of the HREC, they are absented from the decision making process relating to that study.**

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007)* and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.

Please be advised that in the instance of an investigator being a member of the HREC, they are absented from the decision making process relating to that study.

On behalf of the Human Research Ethics Committee, I would like to wish you every success with your research endeavour.

Yours truly,

Anne Carle
A/Executive Officer – Research, Ethics and Governance Unit
The Prince Charles Hospital

Office	Postal	Phone
Research, Ethics & Governance Office The Prince Charles Hospital	Administration Building, Lower Ground Rode Road, Chermside Q 4032	(07) 3139 4500 (07) 3139 4198

Enquiries to: R&ETPCH@health.qld.gov.au
Office Ph: (07) 3139 4198
(07) 3139 4500
Our Ref: Approval Amendments

Queensland Government

12 February 2014

Human Research Ethics Committee
Metro North Hospital and Health Service
The Prince Charles Hospital
Administration Building, Lower Ground
Rode Road, Chermside QLD 4032

Miss Vicky Woodhead
The Prince Charles Hospital

Dear Miss Vicky Woodhead

Re: HREC/12/QPCH/293: Validation of the short-form Dizziness Questionnaire, in the Emergency Department and Early Medical Assessment Unit, to facilitate referral of older fallers and those with dizziness to physiotherapy

I am pleased to advise that The Prince Charles Hospital Human Research Ethics Committee reviewed the amendments submitted and upon recommendation, the Chair has granted approval for the following:

- Protocol Version 6 dated 12 December 2013
- Participant Information Sheet and Consent Form Version 6 dated 17 January 2014
- Addition of site Brighton Rehabilitation Unit

The committee acknowledges the receipt of:

- Letter of support from Maryann Schubert. There is no further need for governance approval for this site.

This information will be tabled at the HREC meeting on 27 February 2014 for noting.

A copy of this approval must be submitted to the relevant Hospital & Health Service Research Governance Officer/s or Delegated Personnel, along with Site Specific documentation, for CEO or Delegate authorisation for each site.

List of approved Sites:

No.	Site
1.	The Prince Charles Hospital
2.	Brighton Rehabilitation Unit

Patient information collected and distributed as part of the previously approved research has been approved in accordance with Section 62 of the Health Services Act and the recent amendments to the Public Health Act Sections 282 and 284. Any change to the collection and or distribution will need to be reviewed by the HREC.

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007)* and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.

Please be advised that in the instance of an investigator being a member of the HREC, they are absented from the decision making process relating to that study.

On behalf of the Human Research Ethics Committee, I would like to wish you every success with your research endeavour.

Yours truly,

Anne Carle
A/Executive Officer – Research, Ethics and Governance Unit
The Prince Charles Hospital

Office	Postal	Phone
Research, Ethics & Governance Office The Prince Charles Hospital	Administration Building, Lower Ground Rode Road, Chermside Q 4032	(07) 3139 4500 (07) 3139 4198

Enquiries to: R&ETPCH@health.qld.gov.au
Office Ph: (07) 3139 4198
(07) 3139 4500
Our Ref: Progress Report

Queensland Government

6 January 2015

Human Research Ethics Committee
Metro North Hospital and Health Service
The Prince Charles Hospital
Building 14
Rode Road, Chermside QLD 4032

Ms Vicky Stewart
Department of Physiotherapy
The Prince Charles Hospital

Dear Ms Stewart

Re: HREC/12/QPCH/293: Validation of the short-form Dizziness Questionnaire, in the Emergency Department and Early Medical Assessment Unit, to facilitate referral of older fallers and those with dizziness to physiotherapy

This is to acknowledge that we have received your Annual Progress Report dated 3 December 2014; your report will be tabled at the Human Research Ethics Committee Meeting held on the 22 January 2015, for noting.

On behalf of the Human Research Ethics Committee, I would like to thank you for sending an informative report on the above study.

Yours sincerely

Anne Carle
Executive Officer – Research, Ethics and Governance Unit
The Prince Charles Hospital

[redacted]

4 March 2013

R&ETPCH@health.qld.gov.au
Enquiries to: Philip_Lee@health.qld.gov.au
Office Ph: (07) 3139 4198
(07) 3139 4500
Our Ref: PL/JL/Final Approval

Miss Vicky Woodhead
Physiotherapy Department
The Prince Charles Hospital

Human Research Ethics Committee
Metro North Hospital and Health Service
The Prince Charles Hospital
Administration Building, Lower Ground
Rode Road, Chermside QLD 4032

Dear Miss Woodhead

HREC Reference number: HREC/12/QPCH/293
Project title: Is the Short-Form Dizziness Handicap Inventory valid to use in the Emergency Department to facilitate referral to physiotherapy for vestibular problems or for older adults being discharged home following a fall?

Thank you for submitting the requested documents for the above project for further review which was received on 14 February 2013. This project was considered by Metro North Hospital and Health Service - The Prince Charles Hospital Human Research Ethics Committee (HREC).

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007)* and the *CPMP/ICH Note for Guidance on Good Clinical Practice.*

I am pleased to advise that the Human Research Ethics Committee has granted final approval of this research project. The documents reviewed and approved on 18 February 2013 include:

Document	*Version*	*Date*
Application NEAF (AU/1/AS10117)		
Scale (The Modified Falls Efficacy Scale)	2	05 February 2013
Dizziness Handicap Inventory (DHI)	2	05 February 2013
Activities Specific Balance Confidence (ABC) Scale	2	05 February 2013
Subjective Assessment	3	05 February 2013
Questionnaire: The Short from Dizziness	2	05 February 2013
Protocol	2	14 February 2013
Questionnaire: The Short form dizziness	3	20 February 2013
Participant Information Sheet/Consent Form	2	05 February 2013

This information will be tabled at the next meeting on 14 March 2013, for noting.