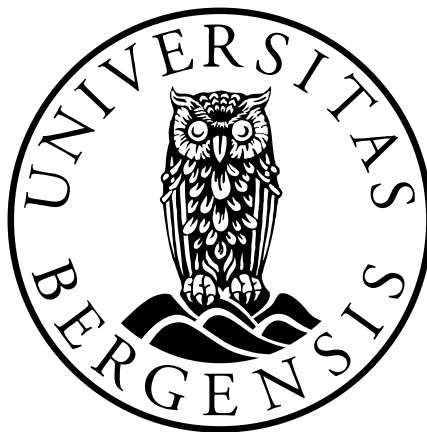


# **Symptoms and signs in patients with long-lasting dizziness**

*Kjersti Thulin Wilhelmsen*



Dissertation for the degree philosophiae doctor (PhD)  
at the University of Bergen

2010

Dissertation date: 29.04.2010



# **Symptoms and signs in patients with long-lasting dizziness**

*Kjersti Thulin Wilhelmsen*



**Department of Public Health and Primary Health Care**

**Section for Physiotherapy Science**

**University of Bergen**

**and**



**The National Centre for Vestibular Disorders**

**Department of Otorhinolaryngology Head-Neck-Surgery**

**Haukeland University Hospital**



---

## Acknowledgements

Music is important to me. It is therefore in place to steal from the standards to reflect on the process. It has truly been a “long and windy road leading me to the door”, resulting in the thesis. The project started once upon..... My colleague Anne Britt Sørsdahl urged me to meet the people working at the Balance Laboratory in Haukeland University Hospital. Examining dizzy patients, they had acknowledged the need to offer physiotherapy treatment to this group of patients. I have had to “pick myself up, dust myself off and start all over again” on more than one occasion going into this unknown field of Norwegian physiotherapy.

Needless to say, without patients there would be nothing “behind the door” today. Otto Inge Molvær, Stein Helge Glad Nordahl and Frederik Goplen introduced me to the medical issues, Susan Herdman to vestibular rehabilitation, and Lucy Yardley to the psychological aspects. You have all contributed to form the basis from where I could develop my thoughts, and I owe my gratitude to each and every one of you.

My supervisor, Anne Elisabeth Ljunggren, who said yes to being tutor without really knowing what I was going to do, but still trusted that I could manage. Your ability to see all the necessary, tiny details without losing sight of the greater lines - not to mention your knowledge of *how to do things*, is impressive. Special thanks to you. The co-supervisors, Stein Helge Glad Nordahl who constantly challenged my desires to “cover everything” in each and every article, and Rolf Moe-Nilssen a connoisseur in balance and statistics, also deserve many thanks. The tutors have been co-authors in the included articles along with Liv Inger Strand, Alice Kvåle, Frederik Goplen and Geir Egil Eide, thank you all for your help.

A lot of people have been involved in seeing this project through, some in more than one position. First and foremost, Heidi Ann Fiske, who took part in developing and running the intervention, Alice Kvåle who took on the job examining the patients. Anne-Lise Tamber working with dizzy patients in Oslo - it was comforting and a great support to know that there were two of us! Anne Kari Skøien and Sturla Gjesdal with whom I looked at Norwegian dizzy patients from a

different angle. Members in the body-awareness group, Heidi Ann Fiske, Alice Kvåle, Randi Sviland, Astrid Ålvik and Anne Grete Paulsberg, deserve many thanks for sharing their experiences. Our “blue trips” at the end of terms have always been a feast. Reidunn and Roger Green assisted in translation processes, Torbjørn Aasen and Erling Hvilen identified patients, Lene Kristiansen read the work, and library staff at Bergen University College providing the very special articles. I am grateful to you all.

Grants from The Norwegian Fund for Postgraduate Training in Physiotherapy paid for my position as a research fellow, The Department of Otorhinolaryngology/Head and Neck Surgery, Haukeland University Hospital gave financial support, and the Department of Physiotherapy, Bergen University College has allocated time in recent years. For this I am grateful. I would also like to add special thanks to Jan Olofsson, head of the Department of Otorhinolaryngology/Head and Neck Surgery for supporting the idea that physiotherapy should be an offer to dizzy patients, and I am extremely pleased that an outpatient clinic has been established in recent years.

Many colleagues and friends at Bergen University College deserve to be mentioned. In particular my superior Mildrid Haugland, for letting me carry on with this work, Anne Kari Skøien for assistance whenever needed in whatever area, Unni Vågstøl who in periods has taken the load off my shoulders, and to Aud Skogen for her enthusiasm! All my other colleagues and friends at the college are also gratefully acknowledged.

It is time to turn to the family which includes the older, current and the future generations. Hugs and kisses to all, but especially to the five youngest who reintroduced important dimensions in life. At last, but not least, Jan, who has been nothing but supportive. The work is done, and I think we are both pleased having come this far. I cannot however, end without going back to the beginning and say “Thank you for the music” to my long dead father who introduced me to it - what would I have done without it through these years?

## Contents

Acknowledgements  
Table of content  
List of papers  
Abstract  
Abbreviations

## Table of content

|   |           |
|---|-----------|
| <b>INTRODUCTION</b>   | <b>14</b> |
| <b>DIZZINESS</b>  | <b>16</b> |
| <b>Dizziness and vertigo</b>  | <b>16</b> |
| <b>Symptoms and signs</b>   | <b>17</b> |
| <b>Symptoms and signs in relation to International Classification of Function (ICF)</b> | <b>18</b> |
| <b>The balance system with focus on the vestibular system</b>                           | <b>19</b> |
| <b>Vestibular compensation</b>  | <b>20</b> |
| <b>Diagnostic groups</b>  | <b>23</b> |
| <b>Epidemiological aspects</b>  | <b>25</b> |
| <b>Treatment of vestibular disorders</b>  | <b>27</b> |
| Traditional Vestibular Rehabilitation Treatment (VRT)                                   | 27        |
| The Modified Vestibular Rehabilitation Treatment programme (MVRT)                       | 29        |
| <b>AIMS OF STUDIES</b>  | <b>31</b> |
| <b>DESIGNS, MATERIAL AND METHODS</b>  | <b>32</b> |

---

|  |           |
|--|-----------|
| <b>Ethics</b>  | <b>32</b> |
| <b>Designs</b>   | <b>32</b> |
| <b>Material</b>  | <b>33</b> |
| Sample 1 (Papers I and II)   | 34        |
| Sample 2 (Papers I, III and IV)  | 35        |
| <b>Methods</b>   | <b>37</b> |
| Dizziness by self-reports  | 37        |
| Balance in gait by accelerometers  | 39        |
| Musculoskeletal function by clinical examination   | 40        |
| Procedures   | 41        |
| <b>Statistical analyses</b>  | <b>43</b> |
| Comment on the use of parametric statistics  | 45        |
| <b>SYNOPSIS OF PAPERS</b>  | <b>47</b> |
| <b>Paper I: Psychometric properties of the Vertigo Symptom Scale - Short Form</b>  | <b>47</b> |
| <b>Paper II: Long-term symptoms in dizzy patients examined in a university clinic</b>  | <b>48</b> |
| <b>Paper III: Improved attenuation of trunk acceleration during walking following intervention in patients with unilateral vestibular deficiencies</b> | <b>49</b> |
| <b>Paper IV: Physical findings in patients with dizziness undergoing a group exercise programme</b>  | <b>50</b> |
| <b>DISCUSSION</b>  | <b>51</b> |
| <b>Methodological issues</b>   | <b>51</b> |
| Papers I, II: Design and material  | 51        |
| Papers III, IV: Design and material  | 52        |
| <b>Issues of validity</b>  | <b>53</b> |
| Instrumental validity, Paper I, II   | 53        |
| Instrumental validity, Paper III   | 57        |
| Instrumental validity, Paper IV  | 58        |
| Validity of findings from self-reports, Papers II, III, IV   | 59        |
| Validity of findings from balance in gait, Paper III   | 61        |
| Validity of findings from the musculoskeletal system, Paper IV   | 63        |



---

|   |           |
|---|-----------|
| <b>Outcome measures</b>   | <b>64</b> |
| Outcome measures in view of ICF                                   | 64        |
| Association between the outcome measures                          | 66        |
| <b>Main findings</b>  | <b>69</b> |
| The observation study: Dizziness and pain                         | 69        |
| The longitudinal study: Results of the MVRT programme             | 72        |
| <b>The rehabilitation programme's potential to promote change</b> | <b>74</b> |
| <b>CONCLUSIONS AND IMPLICATIONS</b>                               | <b>76</b> |
| <b>REFERENCES</b>   | <b>79</b> |

## **Appendices**

1. Overview of Cawthorne - Cooksey's exercise programme for compensation of vestibular dysfunction based on Cooksey, Hecker, and Dix
2. The Vertigo Symptom Scale (VSS) long version and the short version (VSS-SF), and the relationship between the two versions
3. Overview of independent and dependent variables
4. The clinical version of the VSS-SF(NV)
5. Errata

## List of papers

**Paper I:** Wilhelmsen K, Strand LI, Nordahl SHG, Eide GE, Ljunggren AE: *Psychometric properties of the Vertigo Symptom Scale - Short form*. BMC Ear Nose Throat Disord 2008, 8: 2.

**Paper II:** Wilhelmsen K, Ljunggren AE, Goplen F, Eide GE, Nordahl SHG: *Long-term symptoms in dizzy patients examined in a university clinic*. BMC Ear Nose Throat Disord 2009, 9: 2.

**Paper III:** Wilhelmsen K, Nordahl SHG, Moe-Nilssen R: *Improved attenuation of trunk acceleration during walking following intervention in patients with unilateral vestibular deficiencies* (Submitted to Journal of Vestibular Research, 17.08.09, resubmitted 24.11.09)

**Paper IV:** Kvåle A, Wilhelmsen K, Fiske HA: *Physical findings in patients with dizziness undergoing a group exercise programme*. Physiother Res Int 2008, 3: 162-165.

Reprints are made with permission from BioMed Central (Papers I & II) and Wiley-Blackwell (Paper IV)

## Abstract

The overall aim of this work is to increase the awareness on patients with dizziness of vestibular origin. Physiotherapists in Norway have until recently paid little attention to these patients, even though they might benefit from treatment by the profession. Substantial aims were to translate the Vertigo Symptom Scale, short form (VSS-SF) into Norwegian (VSS-SF(NV)), to explore the instrument's measurements properties and to use the instrument to gain knowledge of the long term development of the condition in dizzy patients. Further aims were to develop a modified program of vestibular rehabilitation therapy (MVRT), and to explore balance control, musculoskeletal function and symptoms following implementation of the intervention in patients. Two samples (Sample 1: N = 503, Sample 2: N = 36), recruited by the National Centre for Vestibular Disorders, Department of Otorhinolaryngology, Head-Neck-Surgery, Haukeland University Hospital were included. In both samples, the mean age was around 50 years, and 60 % were women. The majority had vestibular related disorders and had complaints of dizziness of long duration.

Following translation of the VSS-SF(NV), the first study comprised a survey on patients in Sample 1. Survey data from the sample, complemented by data from Sample 2, were used to explore the instrument's measurement properties. Two subscales (vertigo/balance, autonomic/anxiety) were identified as in the original scale, and the VSS-SF(NV) revealed satisfactory discriminative abilities. With respect to evaluative properties, sensitivity to change was satisfactory, but responsiveness of the Norwegian version of the scale should be examined in future studies.

The second study combined survey data with medical chart information on patients in Sample 1. The latter was registered median (interquartile range, (IQR)) 4.6 (4.3) years earlier. Survey data gave information on the current state of dizziness, while medical chart

data (symptom duration, neck pain, sway and diagnosis) in addition to sex and age, were used to explore potential prognostic factors. Severe dizziness, seen among those claiming current dizziness, was mostly related to problems with balance. More than half of the total group reported neck pain at the time of the survey, and dizziness in this sub-group was more severe than in those without neck pain. Symptom duration and neck pain predicted overall dizziness. Balance related dizziness was also predicted by these variables, in addition to sway and age. Neck pain was the only predictor of autonomic/anxiety related dizziness. The observed persistence and severity of dizziness may raise questions whether more efforts should be directed towards identifying the type of dizziness, rather than at diagnostic categorization when long-lasting dizziness is the issue. Questionnaire-based evaluations could assist in this process, and provide a better basis for specific rehabilitation. The implication of the findings may also raise questions with respect to treatment and referral routines for these patients.

In the third study, a one-group pre-post test design was used to test patients from Sample 2 before and after the MVRT intervention. Focus was on balance control and dizziness. Two accelerometers positioned at upper and lower trunk detected body accelerations during gait. Results revealed attenuation pattern at trunk level in a cranial direction similar to that of healthy. Following intervention, increased stability of upper and increased mobility of lower trunk were identified, and also improvement in gait characteristics like cadence and step-length. The findings are compatible with improved control of balance, and were accompanied by improvement in self-reported balance by the VSS-SF(NV).

The one-group pre-post design was also used in the fourth study which focused on musculoskeletal function. Patients in Sample 2 were examined by the Global Physiotherapy Examination (GPE-52) comprising 52 standardized items classifying the musculoskeletal

system in 5 domains (posture, respiration, movement, muscle, skin). Prior to the MVRT intervention, musculoskeletal dysfunction was seen globally and also within the 5 domains indicated by higher scores than that of healthy persons. Following intervention, the musculoskeletal function improved. Decrease in the GPE-52 sum-scores globally and in the respiration and in movement domains, was found. Improvement in the latter was particularly localised to the upper body region. Self-reported symptoms relating to balance on the VSS-SF(NV) did also improve.

Based on the findings in the present work, it looks as if dizziness manifests and persists over time in some patients. The findings raise questions regarding the existing treatment and referral routines, and the need to offer organised vestibular rehabilitation at some point in time. As access to physiotherapy is dependent on referral from medical doctors, a closer collaboration between physiotherapy and the medical profession on this matter is desirable. A modified program of vestibular rehabilitation may improve the control of balance by promoting of more effective trunk attenuation and bodily movement strategies, and also improve self-perceived balance problems.

## Abbreviations

|         |  |
|---------|--|
| ANOVA   | analysis of variance   |
| AP axis | antero-posterior axis  |
| AUC     | area under the receiver operating characteristic (ROC) curve |
| BPPV    | benign paroxysmal positional vertigo                         |
| CDP     | computerized dynamic posturography                           |
| CI      | confidence interval  |
| CNS     | central nervous system                                       |
| COM     | centre of mass   |
| CVI     | chronic vestibular insufficiency                             |
| DGI     | Dynamic Gait Index   |
| EFA     | exploratory factor analysis                                  |
| GLM     | general linear model   |
| GPE     | Global Physiotherapy Examination                             |
| HRQOL   | health related quality of life                               |
| ICC     | intraclass correlation coefficient                           |
| ICF     | International Classification of Function                     |
| IQR     | interquartile range  |
| ML axis | medio-lateral axis   |
| MVRT    | modified vestibular rehabilitation therapy                   |
| NPPT    | Norwegian Psychomotor Physiotherapy                          |
| NCVD    | National Centre for Vestibular Disorders                     |
| PCA     | principal component analysis                                 |
| PCMCIA  | PC data storage card fitting a modem slot                    |
| QoL     | quality of life  |
| RCT     | randomized controlled trial                                  |
| RMS     | root mean square   |

---

|                |   |
|----------------|---|
| ROC            | receiver operating characteristic                             |
| ROM            | range of motion   |
| SCC            | semicircular canal  |
| SCLT           | social cognitive learning theory                              |
| SD             | standard deviation  |
| SDD            | smallest detectable difference                                |
| SF-36          | Medical Outcome Study Health Survey Questionnaire, Short-Form |
| SOT            | sensory organization test                                     |
| S <sub>w</sub> | within-subject standard deviation                             |
| UCLA-DQ        | University of California, Los-Angeles-Dizziness Questionnaire |
| UVD            | unilateral vestibular disorder                                |
| V axis         | vertical axis   |
| VCR            | vestibulo-collic reflex                                       |
| VOR            | vestibulo-ocular reflex                                       |
| VRT            | vestibular rehabilitation therapy                             |
| VSR            | vestibulo-spinal reflex                                       |
| VSS            | Vertigo Symptom Scale   |
| VSS-A          | Vertigo Symptom Scale-autonomic/anxiety sub-scale             |
| VSS-SF         | Vertigo Symptom Scale-Short Form                              |
| VSS-SF(NV)     | Vertigo Symptom Scale-Short Form, Norwegian Version           |
| VSS-V          | Vertigo Symptom Scale-vertigo/balance sub-scale               |
| WHO            | World Health Organisation                                     |

## Introduction

The thesis is based on four papers which are part of a project carried out in the period 2002–2006 at the University of Bergen, Department of Public Health and Primary Health Care, Section of Physiotherapy Science in co-operation with the National Centre for Vestibular Disorders (NCVD). The NCVD, established in 2000, is localized in the Department of Otorhinolaryngology, Head-Neck-Surgery, Haukeland University Hospital. Approximately 800 patients are examined in the NCVD for problems related to dizziness on an annual basis. As physiotherapist, I have been part of the team since the start.

Dizziness is a non-specific symptom caused by many different pathophysiologic mechanisms [1]. It can be understood as an umbrella term for a wide spectre of sensations that can be a normal reaction, or associated with pathology depending on the situation and setting. Dizziness is a transient problem in most people. For some it may however, persist and lead to functional problems, resulting in social isolation, reduced work capability and quality of life (QoL). Dizziness as a subsidiary problem is frequently seen in physiotherapy, and it is an impression that advice like “avoid situations provoking ...” or, “you’ll have to learn to live with ....” are given. Patients with dizziness as a primary symptom have traditionally not been treated by Norwegian physiotherapists, nor has there until recently, been focus on this group of patients in the basic education of the profession.

Treatment of people with dizziness was set on the agenda in England more than 60 years ago by T. Cawthorne and F.S. Cooksey [2]. Patients suffering from post-concussion syndromes and vestibular disorders were treated by active exercises. It was recognised that activity improved the prognosis, particularly if exercises that provoked dizziness were included [2]. An outline of the programme which was offered in a class setting can be found in Appendix (Table 1). A renewed interest regarding dizzy patients started in the late 1980-



ties with the increased awareness of the vestibular system's role in the control of balance [3]. Today several professions are involved in rehabilitation of these patients. Although long-lasting dizziness has psychological overtones, it is important to address the physical symptoms and signs [4-6]. In an earlier article it was claimed that [7]: "..... it is early and efficient physiotherapy that may be the decisive factor between a return to normal activity, or a life of chronic invalidism". Although this might be too strong a statement, it is probably true that some patients with long-lasting dizziness could benefit from vestibular rehabilitation given by physiotherapists. It is therefore a problem that referral to physiotherapy is relatively uncommon and not offered routinely, even on the international arena [4,8-10]. The present thesis will hopefully increase the awareness of this patient population among physiotherapists in Norway.

## Dizziness

### Dizziness and vertigo

The present work focus on patients referred to The National Centre for Vestibular Disorders by their doctors with persistent complaints of dizziness. Dizziness reflects altered orientation in space, indicating a discrepancy between internal sensation and external reality, creating sensory conflicts between the vestibular, visual, and somatosensory systems [11]. Dizziness can be caused by disorders in any of these systems, or it can be a central problem involving the integration and weighting of the different modalities and their relation to memory [11].

A variety of terms: imbalance, swaying, drunkenness, spinning, floating, giddiness, fainting, feeling unreal, walking on clouds, disoriented or light-headed wooziness [12,13] are used by lay-people to describe dizziness. The most common type of dizziness is vertigo [14]. According to The American Academy of Otolaryngology-Head and Neck Surgery, vertigo is defined as a “sensation of motion when no motion is occurring relative to earth’s gravity” [12]. This does not delimit vertigo in relation to dizziness, but rather implies that any type of motion can qualify as vertigo [12]. In a series of population studies from Germany [15-17] the term *vestibular vertigo* comprising 1) rotational vertigo 2) positional vertigo and 3) recurrent dizziness with nausea *and* either oscillopsia *or* episodic imbalance, was used. The first two categories are fairly specific, denoting vertigo while the last is a wide category. In another recent study [18], *dizziness* was defined as a) dizziness in which things spin around, b) unsteadiness, light-headedness or feeling faint, c) dizziness in which the respondent seems to move. From this, the spinning and moving sensations of vertigo can be recognised, as well as a more unspecified category. The definitions seem however, to cover the same sensations. In cases of mild or partly compensated vestibular disorders dizziness,

more than well-defined vertiginous sensations are perceived [12]. It might be difficult to differentiate between the various concepts [19]. In the present work dizziness and vertigo are considered synonyms.

## **Symptoms and signs**

According to Taber's cyclopedic medical dictionary [20], symptoms can be defined as any perceptible change in the body or its functions which indicates disease or phases of disease. Symptoms can be classified as objective, subjective, cardinal; principal and important, and as constitutional; pertaining to the whole body. Symptoms classified as subjective, are per se unobservable [20], although symptoms can be expressed through behaviour. This aspect is not focused on in the present work. Observable indications are referred to as objective signs [20]. Physical signs are any objective evidence of an abnormal nature in the body or its organ, more or less definitive and obvious, and apart from the patient's impression.

For many of the patients included in this work, dizziness most likely started as an acute event associated with autonomic symptoms and general feelings of malaise [21]. The symptoms can thus be considered being cardinal and constitutional [20]. Dizziness as a symptom is an internal and private experience, i.e. it is described and interpreted differently by different people [13] and cannot be subjected to social validation [20]. Dizziness was most likely also a cardinal symptom when the patients came for medical examination at the NCVD years later, even though the nature of dizziness might have changed. The sensations at this stage could most likely be described as vague feelings of dizziness and visual problems, associated with unsteadiness. Unsteadiness as a perception can be classified as a symptom [20]. The dizziness-unsteadiness sensation might be difficult to separate. Unsteadiness resulting in a fall affects the whole body. As such it can be observed and

considered a sign [20]. Signs related to unsteadiness could also be less obvious and manifest indirectly as reduced control of balance resulting in for example, reduced gait speed [22].

Another, but less focused feature of patients with long-lasting dizziness relates to symptoms and signs from the musculoskeletal system. To the extent that problems in this system are recognized, they are considered secondary to dizziness [23] and the result of compensatory strategies. The strategies could result in restricted body movements, muscle tension, fatigue and pain [24]. Over time, flexibility and ability to relax, muscle tension, respiration and posture are negatively affected. Musculoskeletal problems can therefore also be classified as constitutional [20]. Some problems from the musculoskeletal system can only be sensed by an individual, i.e. pain, which thus reflects symptoms. Other aspects such as reduced range of motion, can also be observed, and reflect physical signs.

In this work, dizziness is understood as a *subjective symptom* while physical characteristics identified in the musculoskeletal system are considered *objective signs*.

### **Symptoms and signs in relation to International Classification of Function (ICF)**

The International Classification of Function (ICF) from the World Health Organization's (WHO) [25] is a classification system describing the functional status associated with health conditions. *Functioning* denotes the positive aspects of the interaction between a person, a health condition and contextual factors, while *disability* is an umbrella term for the negative. The component *body function* comprises physiological and psychological functions, while *body structure* refers to anatomical parts of body systems. *Impairment* relates to abnormal function in body systems. In the component *activities and participation*, *activity* is the execution of a task or action by a person at an individual level while *participation* represents

the societal perspective of functioning. The corresponding negative connotations are termed *activity limitations* and *participation restriction*, respectively.

In view of ICF [25] it is possible to describe the health condition in patients with long-lasting dizziness. For many of our patients, original symptoms and signs were the result of an abrupt, one-sided loss of vestibular function. This could be caused by damage to body structure (e.g. nerve as in vestibular neuritis), resulting in an asymmetric relationship between the functionally coupled (bilateral) peripheral vestibular system, leading to dizziness and the commonly associated unsteadiness. Although the asymmetry may be lifelong [13], it might be compensated for at higher cortical structure. However, patients in our samples may have had problems with the compensation, and were left with persistent problems. Over time the problems may have restricted activities and participation according to their expectancy [25].

### **The balance system with focus on the vestibular system**

The overall balance system comprises 3 sub-systems: the vestibular, visual and somatosensory systems. Input from all systems is integrated in the central nervous system (CNS) and accompanied by appropriate muscular responses to maintain balance control [26]. Balance is maintained by keeping the projected centre of mass (COM) within stability limits [27]. Stability limits is a relative concept influenced by individual characteristics, the task and environmental factors [27]. The ability to retain balance is constantly challenged by internal and external demands. Damage in any sub-system could influence the capability to remain upright and balanced, and environmental factors could further challenge this ability.

The peripheral vestibular system consists of 5 motion sensors located on either side of the head. The sensors are functionally coupled [28] and consist of 3 co-planar semicircular canals (SCC) arranged orthogonally, and 2 otolith organs (utricle, sacculus). The SCCs are

responsible for detecting change in angular velocity of the head, working in a push-pull fashion with its opposite fellow. Increase in impulses on one side results in an equal decrease on the other. The otolith organs sense linear acceleration and static tilt of the head with respect to gravity, and responds selectively to head motion in specific directions [28]. During (loco)motion, information from the peripheral sensory apparatus is submitted to centrally located, primary processors (the vestibular nucleus complex) in the CNS. The processors are responsible for fast connections between afferent and efferent impulses, and influenced by visual and somatosensory systems. Information is further submitted to the cerebellum, which monitors and readjusts the vestibular processes if necessary. Extensive connections exist between afferent structures and efferent activating systems. The most important reflexes are the vestibulo-ocular (VOR), the vestibulo-collic (VCR) and the vestibulo-spinal (VSR) [28]. The VOR drive extraocular muscles and are responsible for co-ordinating eye-head movements and stabilization of images on the retina of the eye. Visual images are stable when VOR gain (the ratio of eye movement velocity to head movement velocity) is equal to 1. Further, the VCR drive skeletal muscles responsible for stabilizing the head on the trunk, while the VSR stabilize the body to prevent falls [28]. The symmetric activity in the primary processors can be disturbed as seen in some diagnostic groups described later. The asymmetry triggers a compensation process.

## **Vestibular compensation**

Vestibular compensation is the process by which a person may recover from unilateral vestibular deficiencies (UVD) [29]. Two main stages of this process; the static and the dynamic compensation, are outlined.

*Static compensation* starts within days, is spontaneous and considered to be a robust process [29,30]. Following abrupt unilateral damage, asymmetry in neural signals to the

coupled motion sensors, gives rise to vertigo and autonomic symptoms, nystagmus (rapid eye movements), head tilt, ocular torsion and skew deviation of the eyes towards the affected side [29,30]. It is associated with postural instability, inadequate compensatory responses to head movement, as well as changes in the perception of body orientation and movement. Symptoms usually fade within 3-5 days. The process restores symmetric activity in the vestibular nuclei [29,30]. One month has been suggested to delimit static and dynamic compensation [31].

*Dynamic compensation* is less robust than the static compensation, and is usually incomplete [29,32]. It is dependent on active input from the visual, vestibular and somatosensory systems [29]. Dynamic compensation is associated with VOR responses [29], which is sub-optimal because of the disrupted push-pull system of the SCCs. Adaptation is driven by movements supplying the necessary error signals (“slips”) across the retina. The process is supported by input from higher cortical structures [33]. The sub-optimal association between VOR and motor behaviour with respect to gain, timing and direction may persist [29,33]. The VSR and VCR responses may also remain disturbed [33] resulting in postural instability. In the dynamic phase, patients may experience partial or complete relapse (decompensation) [29], with return of symptoms associated with the acute phase. Decompensation can be triggered by stressful events, and/or reduction in cerebellar function [29].

Dynamic compensation takes time, and is not always a straight-forward process. Heterogeneous aetiologies may lead to different compensation processes, but equivalent losses could also be compensated differently [29]. Roughly, 30 % of patients are suggested to compensate poorly [34], resulting in a condition referred to as chronic vestibular insufficiency (CVI) syndrome [29]. CVI is characterized by sensations of disequilibrium and oscillopsia (sensation of apparent movement of visual field, evident in quick head

movements). No particular markers that identify the well-compensated from the poorly-compensated patients have been found [34]. Active head and body movements to produce error signals in the early phase, seem important for rate and level of recovery of VOR and postural control [30,33,35]. Some patients are considered effectively compensated as new sensory and behaviour strategies develop. The new strategies can be more or less functionally oriented. Replacing an ineffective VOR by voluntary catch-up saccadic (rapid changes in eye position) eye movements [29,33], or substitution of lost vestibular input by input from the somatosensory systems, may be considered functional strategies [33]. A less functional, but probably very common compensatory strategy is to avoid head movements [6]. Sub-optimal function is masked in the developed strategies [29], but permanent deficiencies are embedded and appear when the system is challenged. A challenging task would be walking. During performance, the deficient system is unable to coordinate head-and eye movements to maintain a clear vision [36].

Recovery has a large subjective component [29] and is influenced by psychological factors, age and motivation [6,29,30]. Compensation can be considered a learning process where non-vestibular sensory input and cognitive-behavioural strategies are suggested to play a role, although the underlying mechanisms are not completely understood [29]. The patients included in the present work have persistent dizziness and associated visual problems and unsteadiness. Problems typically present in ambulatory tasks and are reinforced in “noisy” situations, such as a crowded and busy supermarket. They could be typical for patient that are sub-optimally compensated and could benefit from relearning programs.



---

## Diagnostic groups

The present work includes patients classified in 6 diagnostic groups.

*Benign positional paroxysmal vertigo* (BPPV) is the most common cause of vertigo [37]. BPPV is characterized by brief episodes of vertigo typically lasting less than 1 minute, precipitated by rapid change in head position, and sometimes associated with postural instability between attacks [37]. The pathological mechanism is primarily explained as canalolithiasis, i.e. debris (otoliths) from the utricle floating freely in the semicircular canals. Debris, with higher density than the endolymph, sinks to the lowest point when the head moves in the plane of the specific canal. The endolymph is forced to move, deflecting the cupula by suction or pressure, depending on the direction of the movement [38]. The condition can be diagnosed (Dix-Hallpike manoeuvre) and treated by physical manoeuvres (e.g. Epley's manoeuvre) [39]. Once the offending stones are removed from the labyrinth, an intact labyrinthine function can be regained. BPPV may occur spontaneously [37], it is seen after head traumas [39], vestibular neuritis [21] and Menierès disease [40]. The condition is most common in women [37], it is often self-limiting and resolves spontaneously within 6 to 12 months [37]. Bilateral involvement ranges 10–20 % [37]. Clinically, instant resolution of symptoms is seen, but long-term resolution is questioned [39,41]. Recurrence rate up to 40 % has been reported [42].

*Vestibular neuritis* is the second most common cause of vertigo [37] characterized by an acute onset of prolonged rotational vertigo exacerbated by head movements. In the acute stage the condition is particularly associated with autonomic symptoms: malaise, pallor, sweating, nausea and vomiting [21,37]. Vertigo is the result of imbalance in tonic vestibular activity of the vestibular nuclei [21]. There is evidence of viral infection in the vestibular nerve [21,37], but well-accepted diagnostic criteria do not exist [21]. Vestibular neuritis is common among the 30-60 years old, with a peak for women in 4<sup>th</sup> decade, for men in 6<sup>th</sup>.

Acute symptoms subside fairly quickly (48-72 hours) [37] with gradual return to normal within weeks [21,37]. In the acute stage, treatment aims at reducing symptoms by medication [21]. Return of peripheral vestibular function can to some extent be expected [29], and recovery is further enhanced by central compensation [21,29]. Some patients have residual non-specific dizziness and balance problems, which are particularly associated with ambulatory tasks [21].

*Menière's disease* is characterized by fullness in one ear, reduction in hearing, tinnitus and vertigo during acute attacks which may last up to 24 hours [37]. Attacks are commonly associated with nausea and vomiting [37], leaving the patient with sensations of postural unsteadiness. Patients are left with a normal or near normal labyrinthine function between attacks [29]. In early stages, hearing may gradually return to pre-attack level, but over time permanent sensorineural hearing loss is common. Spontaneous attacks diminish in frequency and severity over the years [37]. However, tinnitus may remain, influencing QoL negatively [43]. The cause remains uncertain, but endolymphatic hydrops as a result of mal-absorption of endolymph is fundamental in the development. Whether this is the actual cause or an observed pathological change, is not clear. Onset is usually within 4<sup>th</sup> to 6<sup>th</sup> decade, and a genetic factor is suggested. Distribution is equal between the sexes, and bilateral involvement is identified in 33-50 % of the cases [37]. Medical treatment, chemical or surgical destruction of vestibular structures are some of the many treatments being offered for relief of fluctuating symptoms [44]. The vertiginous attacks usually become weaker over the years.

*Vestibular schwannomas* (acoustic neuroma) is a nerve sheath tumor localized in the internal auditory canal or cerebellar-pontine angle usually presenting with progressive sensorineural hearing loss [44]. In some cases the condition starts with vestibular symptoms and sudden hearing loss [44], and dizziness is reported as the symptom having the greatest

impact on health-related QoL [45]. Diagnosis is confirmed by image technology. Treatment options are conservative, or surgical, depending on size, location and rate of growth of the tumor, and associated symptoms. If surgically treated, the patient may be left with complete, permanent unilateral vestibular dysfunction [46] which triggers a compensation process. Symptoms may resolve within weeks after surgery, but some patients do not recover fully and have persistent discomfort [46].

*Cervicogenic dizziness* is defined as “a non-specific sensation of altered orientation in space and disequilibrium, originating from abnormal afferent activity in the neck” [47]. It is common following neck injuries [47,48] and suggested to result from abnormal input of signals to the vestibular nuclei from proprioceptors in the upper cervical region. A cyclic pattern is implied: muscle spasm arising from abnormally functioning cervical proprioceptors contributing to dizziness, which then contributes to muscle spasm [47]. The condition’s existence is questioned by some [49]. It is diagnosed as a clinical entity in our clinic based on exclusion of other possible causes, as done by others [47,48,50]. It is also referred to as cervicogenic, cervical or musculoskeletal vertigo [47,50,51].

*Non-otogenic dizziness* or “others” is a diagnosis of exclusion according to the classification system in our clinic. Patients present with a history and similar symptoms as that of vestibular disorders. Classification into more clearly defined groups, is not possible by means of clinical and laboratory tests.

## **Epidemiological aspects**

Studies on dizziness differ regarding the concept of dizziness, by inclusion of different populations and age groups, different case definitions, data collection methods and also different measures of prevalence and incidence. Direct comparison between studies is therefore complicated. In general population studies, the frequency of dizziness is reported to

range from 10 % to 30 % [17,52-55]. In a study from Germany, the lifetime prevalence of dizziness/vertigo was 29 %, 1-year prevalence 23 %, and 1-year incidence 3 % [17]. The corresponding figures for vestibular vertigo were 7.4 %, 4.9 %, and 1.4 % respectively [17]. Studies recruiting participants via health care registers and primary care in the Netherlands, England and Scotland, showed that 20-25 % reported dizziness-related problems [9,18,56,57]. Among these, 22-29 % visited the general practitioners for this reason. A Spanish group, studying a sample considered representative for the general population, reported that close to 2 % consulted primary care centres for vertigo, the annual incidence was 0.8 % [58]. In Germany, the annual incidence of dizziness/vertigo was reported as 1.8 % with 0.9 % for vestibular vertigo [17]. Referral from primary to specialist care institutions in Scotland for dizzy- and unsteadiness was 4 % in a 1-year period [9,18], while in a study from England (no indication of time) showed that 11-20 % were referred from primary to hospital care [9,18]. Dizziness is most common in women [9,17,18,52-54,57,58] and shows an increasing trend with age in most studies [17,18,54], with a marked increase among the eldest [53,54].

In Norway, 5 % of the general population report substantial problems with dizziness [52]. It is the main reason for visit to primary care in 2 % of the consultations (no indication of time) [59]. According to the Norwegian National Insurance Service, more than 70 % of those with complaints of dizziness are in the working age group. Dizziness may result in time away from work, force a change in occupation or abandon professional activities, hamper everyday activities, lead to social isolation and thereby influence QoL [17,18,56,57,60]. In 2008, 294 million Norwegian kroner was paid as compensation for sick leave for this reason. Another 16 days paid by the employer can be added. Although dizziness/vertigo is a relatively rare cause of long-term certified sickness absence in Norway

---

[61], long-term sickness absentees with dizziness/vertigo have a substantial risk for obtaining disability pension [61].

## **Treatment of vestibular disorders**

No common treatment has been identified for the whole spectre of vestibular disorders [32], but symptomatic treatment is offered along several lines: pharmacological, physical, surgical [32], and cognitive-behavioural [5]. Physical approaches, i.e. traditional vestibular rehabilitation therapy (VRT) and a modified version of this (MVRT) are described.

### **Traditional Vestibular Rehabilitation Treatment (VRT)**

Vestibular rehabilitation treatment (VRT) originated in England (Appendix, Table 1) in the 1940-ties [2,62]. VRT aims at improving visual acuity and balance by reducing dizziness through central compensation [63,64], as well as improve physical condition and the general level of activity. Goals further aim at increasing knowledge, promote normal ways of living, and reduce fear and social isolation [64]. The core component is exercises that provokes dizziness [64,65] and different types are used for this purpose [64]: *Vestibular adaptation exercises* target long-term changes in the vestibular-ocular system by combining visual fixation and head movements to introduce error-signals required for compensation. *Substitution exercises* enhance sensory input to the system by stressing the use of the visual and somatosensory cues. *Habituation exercises* using repeated exposure to provocative stimuli, should over time result in a reduction of responses, i.e. sensation of dizziness. The three strategies are combined and commonly given as customized treatment based on the individual patient's needs [64,66,67].

A Cochrane study found moderate to strong evidence that VRT was safe and effective in cases of BPPV, vestibular neuritis, labyrinthitis, unilateral Menière's disease and vestibulopathies following surgical procedures [68]. Another systematic review [69] found strong scientific evidence for effectiveness in vestibular hypofunction, multisensory dizziness and Menière's disease. Moderately strong evidence for effectiveness of VRT was seen following vestibular surgery, while insufficient evidence was seen in dizziness of neurological origin, BPPV, phobic postural vertigo, and dizziness associated with whiplash disorders of the neck. Inclusion criteria and diagnostic terms differ between the studies [68,69], but both studies seem to agree that VRT is effective in most vestibulopathic groups of patients. There are however, reports indicating that only 65 % may find VRT beneficial [70]. VRT is driven by the presence of symptoms more than specific diagnoses and underlying causes [68]. Patients with stable disorders are potential candidates [37,68]. Improved function can be expected after 6 weeks, possibly influenced by the duration of problems [64].

New approaches, such as optokinetic stimulation in virtual reality environments and biofeedback systems [65,71-73] have been introduced. Movement systems such as Tai Chi [74], and treatment programmes with focus on breathing rhythm [75] have also been tested. The nature of the compensation process suggests that there could be many ways to treat patients with vestibular deficiencies [30]. It is an open question if some form on VRT is more effective than other [68].

---

## **The Modified Vestibular Rehabilitation Treatment programme (MVRT)**

A modified vestibular rehabilitation treatment programme (MVRT) was developed for the present work. The approach explicitly aims at the relief of musculoskeletal symptoms, at reducing the fear of being active and moving about, in addition to the aims of traditional VRT.

The MVRT programme is based on Norwegian Psychomotor Physiotherapy (NPPT) which focus on the body-mind interaction [76] by seeing the body as a functional, integrated unit where respiration, muscles, posture and movement are considered interdependent. It is assumed that the whole body reacts to physical and psychological strain over time, affecting the flexibility and ability to relax, muscle tension, respiration and posture [76]. The tradition can be identified as a form of body awareness therapy [77] emphasizing body consciousness to deepen body experience. In MVRT, special attention is paid to the musculoskeletal system to promote the stability-flexibility dimension of the body, bearing in mind that compensation is promoted by dizziness provoking movements. The classical adaptation/habituation exercises of VRT are mostly incorporated in functional movements in the MVRT. The individual is made aware of bodily changes by “site and situation” reflections in relation to performance. Progression is by varying the speed and range of motion, the starting position and ground conditions, creating increasingly more challenging tasks and situations. Various relaxation techniques are included, and each session ends with dialog/discussion focusing on specific topics and/or today’s experiences. The intervention is further described in **Paper IV**.

The theoretical foundation of the MVRT draws on social cognitive learning theory (SCLT) [78] which acknowledges the interplay between the individual, behaviour and environment. Direct and indirect ways of learning are central, and *self-efficacy*, defined as an individual’s belief in the ability to master [78] is a key in the learning process as it can be influenced through self-reflection and external reinforcement. The coping strategies in the

fear-avoidance model [79]: confrontation and avoidance are acknowledged. The first may reduce fear, the latter which is suggested to maintain or exacerbate fear, is a typical strategy used by many of the patients included in our studies. Direct learning through practice of movement is the key to change behaviour: *Practice* may change *Attitude* and *Knowledge* (*PAK-model*) [80]. *Movement* in a wide sense, i.e. from specific exercise to behavioural strategies in everyday activities, is considered the active, confrontational coping strategy. Practicing movements also has cognitive elements as *practice* requires that the patient is focused. The interdependent self-efficacy and mastering incorporate the above elements and implies that if convinced, extraneous resources can be brought forward in attempts to reach a wanted goal. This may enhance beliefs and improve skills, which further influence self-efficacy positively and is the basis for our approach to the patients included in this work.



## Aims of studies

The purpose of the present investigation was to gain knowledge of symptoms and signs in patients with long-lasting dizziness. Further, to implement a modified programme of vestibular rehabilitation therapy (MVRT) in patients with long-lasting dizziness, and to explore whether control of balance and musculoskeletal functions could be improved following the MVRT programme. The specific aims of the studies were to:

- Translate and adapt the Vertigo Symptom Scale, Short Form (VSS-SF) into Norwegian, and to examine measurement properties of the instrument (**Paper I**).
- Explore the long-term development of dizziness in groups of patients examined in a university clinic, and factors that could influence the prognosis (**Paper II**).
- Implement a modified programme of vestibular rehabilitation therapy (MVRT) for patients with long-lasting dizziness (**Papers III, IV**).
- Examine attenuation of trunk acceleration during gait in patients with long-lasting dizziness. Based on an assumption that attenuation could be influenced by a programme of MVRT, change in trunk attenuation was explored following intervention (**Paper III**).
- Examine localization and extent of dysfunctions in the musculoskeletal system in patients with long-lasting dizziness. Based on an assumption that the musculoskeletal system could be influenced by a programme of MVRT, change in musculoskeletal function was explored following intervention (**Paper IV**).

## Designs, material and methods

The thesis can be divided into 3 parts. The first part looks into the measurement properties of a self-report questionnaire (Vertigo Symptom Scale–Short Form, (VSS-SF)) translated into Norwegian (VSS-SF (NV)) (**Paper I**). The second is an observational study focusing on symptom status (**Paper II**). The third part is a longitudinal study including two sub-studies focusing on balance control (**Paper III**) and musculoskeletal function (**Paper IV**).

### Ethics

The project was approved by the Regional Committee for Medical Research Ethics in Western Norway (West 143.98) with permission to establish a data base from Norwegian Social Sciences Data Service (NSD) (8766/2005008708), and carried out in accordance with the Helsinki Declaration. Written informed consent was obtained from all patients. Written information was submitted as part of the questionnaires in the observational study. The informed consent was returned with the questionnaires in Sample 1. In Sample 2, written and oral information were given, and informed consent was signed during the first test session.

### Designs

To explore the measurement properties of the VSS-SF (NV), cross-sectional (survey) and longitudinal (test-retest) designs were used [81] (**Paper I**). In the observational study, cross-sectional (survey) and retrospective (archival) designs [82,83] were combined to examine the long-term development of dizziness and the predictive ability of some known factors (**Paper II**). The one-group pre-post test design [81] in the intervention study, was used to examine balance control associated with attenuation of trunk accelerations (**Paper III**), and the extent

and localisation of musculoskeletal dysfunction (**Paper IV**) before and after a modified programme of vestibular rehabilitation.

## **Material**

Two samples included patients recruited from the NCVD. All patients had been examined by otolaryngologists for persistent dizziness. The examination was supported by standard otoneurological laboratory tests as described in the laboratory's protocol, i.e. audiometry (pure tone and speech), static posturography (eyes open and closed), electronystagmography with bithermal caloric tests, tests for spontaneous and positional nystagmus, ocular smooth pursuit, and saccades. Details of the samples are given in Table 1.

**Table 1: Descriptives of patients in Sample 1 and Sample 2**

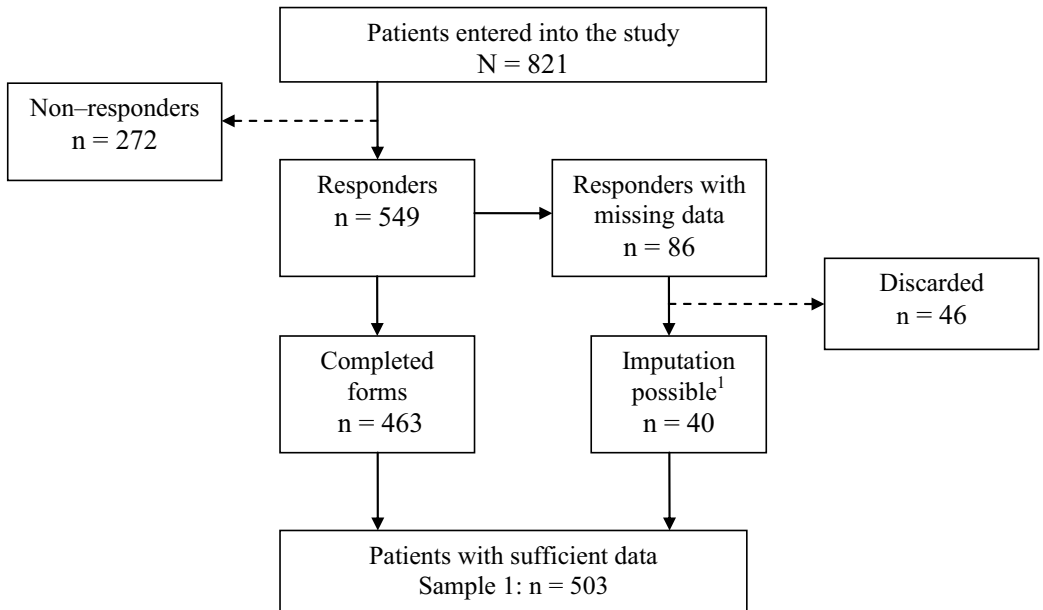
|   | <b>Papers I,II</b>       | <b>Papers I, III, IV</b> |
|---|--------------------------|--------------------------|
|   | Sample 1<br>N = 503      | Sample 2<br>N = 36       |
| Female participants, n (%)  | 303 (60)                 | 22 (61)                  |
| Age in years, mean (SD)   | 50.0 (11.7)              | 48.4 (11.6)              |
| Vestibular diagnoses, n (%)   | 311 (62)                 | 30 (83)                  |
| Caloric asymmetry, mean (SD)  | 21.0 (18.3) <sup>1</sup> | 38.3 (33.2)              |
| Eyes open, sway path in mm, mean (SD)                                   | 630 (410) <sup>2</sup>   | 629 (1484)               |
| Eyes closed, sway path in mm, mean (SD)                                 | 1040 (750)               | 1713 (1533)              |
| Symptom duration in months: debut to medical examination, median (IQR)  | 21.5 (49.0) <sup>3</sup> | 12.5 (18.8)              |
| Symptom duration in months: medical examination to survey, median (IQR) | 57.0 (50.0)              |                          |
| Neck pain at baseline, n (%)  | 135 (27)                 | 8 (33) <sup>4</sup>      |
| Use of medication in relation to dizziness, n (%)                       | 40 (8)                   | 0 (0)                    |
| Still dizzy, n (%)  | 365 (73)                 | 36 (100)                 |
| Symptom severity in the still dizzy by VSS-SF(NV), mean (SD)            | 17.2 (10.1)              | 15.8 (9.0)               |
| Spells of dizziness within the last month, n (%)                        | 295 (59)                 | 36 (100)                 |

<sup>1</sup>n: 420, <sup>2</sup>n: 467, <sup>3</sup>n: 442, <sup>4</sup>n: 24, SD: Standard deviation, IQR: Interquartile range

### **Sample 1 (Papers I and II)**

The cohort was recruited from patients examined between 1992 and 2001 (N = 2067) at the NCVD. Primary classification was into one of four categories (vestibular, neurological, injuries, and non-vestibular). Further sub-classification into diagnostic groups based on medical chart information, was done retrospectively by experienced otolaryngologists. Identification of patients for the survey study was based on age (18-70 years) and diagnoses. Diagnoses in the vestibular category comprised patients with the following peripheral vestibular diagnoses: BPPV, vestibular neuritis, Menière's disease and vestibular

schwannoma. Central vestibular disorders were excluded. The non-vestibular category included: cervikogenic and non-otogenic dizziness. The inclusion criteria were met by 821 patients (Figure 1). The survey was undertaken in May-June 2002.



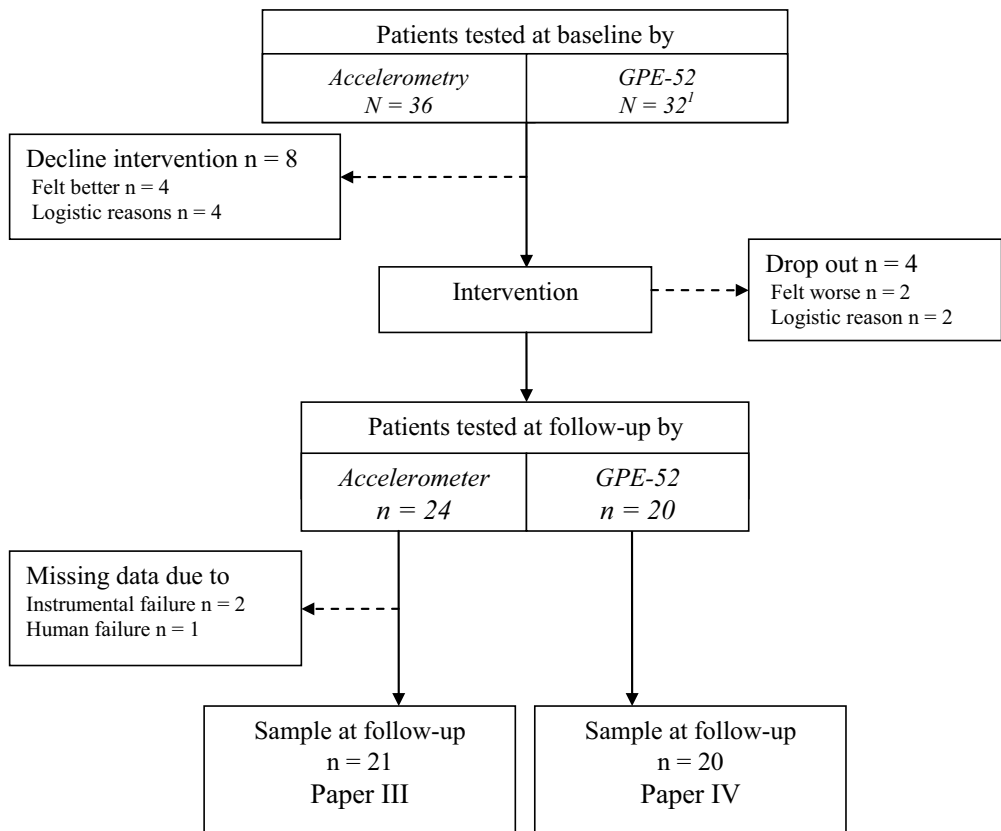
**Figure 1: Sample 1, recruitment of participants to the survey (Papers I and II)**

<sup>1</sup> Imputation by the arithmetic mean of the respective vertigo/balance and autonomic/anxiety sub-scales of the VSS-SF(NV) if one or two items were missing [84].

## Sample 2 (Papers I, III and IV)

Sample 2 consisted of 4 cohorts included prospectively. Patients examined at the NVCD between 2003 and 2005, were approached if the diagnosis was compatible with uncompensated vestibular disorder following vestibular neuritis. Exclusion criteria were evidence of primarily central vestibular disorder, progressive vestibular pathology, genetic

hearing loss and/or neurological/musculoskeletal/visual/psychiatric disorders. Potential participants should live in the vicinity of the treating institution (max 1.5 hours by public transport), and 93 patients were identified and invited to participate in the project. Written information was followed by a telephone call, after which 36 patients agreed to be tested by physiotherapists. Potential candidates declining participation ( $n = 57$ ) claimed to be better from the dizziness, some gave logistical reasons (day, time), while others felt they lived too far from the treating institution. Details of inclusion can be found in Figure 2.



**Figure 2:** Recruitment of participants (Sample 2) to the intervention study (Papers III, IV)

<sup>1</sup>The GPE-52 examination was not available at the time for 4 patients (**Paper IV**)

---

## Methods

The following section focuses on the 3 outcome measures. All the included variables are presented in Appendix, Table 2.

### Dizziness by self-reports

The Vertigo Symptom Scale (VSS), which is a self-administered, condition specific instrument capturing symptoms of dizziness within the last 12 months, was published in England in 1992 [85] (Appendix, Table 3). The instrument aims at isolating the relative contribution of vertigo/balance (VSS-V) and autonomic/anxiety (VSS-A) on dizziness. Variables were generated from former interviews with members of the target group and from literature [85]. The original instrument contains 34 items and was introduced with a one-year recall period [85], although shorter recall period has also been used [65]. The measurement properties of the VSS have been explored in several studies [85-89]. The scale has been translated into other languages [89-91] and is frequently used for descriptive purposes [55,92-94] and in intervention studies [65,95,96] in patients recruited from primary and secondary care institutions.

The modified, short form of the VSS (VSS-SF) (Appendix, Table 2) was introduced in 1998 to assess the benefit of therapy [23,97]. The short version, selected for the present work, consists of 15 items extracted from the VSS. Vertigo/balance (8 items) and autonomic/anxiety (7 items) sub-scales can be identified. The recall period is one month. The items are scored on a 5-point Likert type of response scale (scale 0-4), and higher scores indicate more problems. Scores can be presented as sum-scores, or as mean scores by dividing the sum-score with the relevant number of items [98]. The short form has been translated into other languages [99,100], it has been used for descriptive purposes [31,100], and in intervention studies [23,43,67,97,101,102]. Satisfactory internal consistencies ( $> 0.70$ )

on the total scale [57,99] and on sub-scales [103] have been reported on the VSS-SF. Long term (6 months) test-retest reliability (0.60) has also been reported [23]. Severe dizziness has been defined as  $\geq 12$  points [67]. The instrument is responsive to change [23,104], and a change  $\geq 3$  points on the VSS-SF has been defined as clinically significant [67].

*The Norwegian version of the VSS-SF:* Permission to translate the VSS-SF into Norwegian and to name it the VSS-SF(NV) (Norwegian version) was granted by Lucy Yardley (**Paper D**). Translation into Norwegian was done according to international guidelines [105-107], i.e. forward and backward translations followed by reviews and modifications. The scale was translated twice by two different groups, each consisted of 3 persons.

Translation was guided by ethnocentric and pragmatic understanding [105,107] which focus on whether a construct is transferable to other cultures. Dizziness can be considered a hypothetical construct, operationally delimited by 2 sub-constructs; vertigo/balance and autonomic/anxiety [23]. It is possible that this made dizziness less abstract and easier to interpret. Words and phrases used by our Norwegian dizzy patients, were recognized from the original short version [23]. A meaningful translation could therefore be supported [105,107]. The number of people involved in the translation could be considered small [108]. However, translations were done twice by two independent teams highly skilled in the English and Norwegian languages and knowledgeable in concepts used by dizzy patients. This could strengthen the translation process [105-107]. The translation seemed to provide a scale with overall conceptual, semantic and technical aspects in line with the original scale [105]. The Norwegian version of the VSS-SF is presented in Appendix. Exploration of the VSS-SF(NV)'s measurement properties was undertaken following translation.



---

## **Balance in gait by accelerometers**

Rhythmic oscillations of the body during gait associated with cyclical movements of the lower limbs [109,110] can be detected by body mounted accelerometers without constraining gait [111,112]. An accelerometer is a force transducer measuring the reaction forces associated with a given acceleration [112], and gradual attenuation of the oscillations can be detected by the device. Acceleration measured in the vicinity of centre of mass (COM) has been suggested as a global indicator of balance control [111,113,114], and has recently been reported in a large number of gait studies on healthy persons and patients with impaired balance control [111]. For patients included in our study, gait can be considered a challenging task, particularly when it comes to control of balance.

Data from the gait tests was collected by two low-inertia (30 gram) triaxial piezoresistant accelerometers (Logger Technology HB, Malmö, Sweden). Test-retest reliability of the instruments has been reported as satisfactory [115]. Segmental positioning of accelerometers has a potential to give information on attenuation processes in respective parts of the body [113,116]. The instrument and procedures have been described in details elsewhere [113,117-119], thus an outline is given. Triaxial accelerometers allow identification of accelerations associated with body oscillations along orthogonally arranged antero-posterior (AP), medio-lateral (ML) and vertical (V) axes. Linear accelerations (g) represented by root mean square (RMS) values can be measured, and reflect the mean amplitude of accelerations across the distance travelled [113], g is the unit of gravity. When a measurement axis is not horizontal, a piezoresistant accelerometer registers a static gravity component in addition to the accelerations caused by the moving body. The gravity component was corrected for by use of an algorithm [118] to assess true dynamic acceleration. Little drift, as well as excellent precision and accuracy has previously been reported [117] for the accelerometers employed in our study. Previous research [120] has

indicated little variability of accelerometers with repeated use. The accelerometers were connected by a 0.60-m coaxial cable to a battery operated portable PCMCA datalogger (Logger Technology HB, Malmö, Sweden). Analogue signals were lowpass filtered at 55 HZ before being sampled at 128 HZ to avoid aliasing.

Accelerometers have been used to register spatio-temporal gait variables in a reliable manner [111,113,118,121,122]. Body accelerations are influenced by gait velocity [113,116], age [123,124] and environmental conditions [125,126]. Trunk accelerometry in ambulatory tasks has been used in several studies on young and elderly healthy [113,119,127-129] as an indicator of balance control, and to study walking patterns in varying environmental conditions [113]. Diverse control strategies have been identified.

### **Musculoskeletal function by clinical examination**

The Global Physiotherapy Examination (GPE) is a modification of the Global Physiotherapeutic Muscle Examination [130] originally developed within the NPPT tradition to examine musculoskeletal dysfunctions in patients met in psychiatric institutions [130]. The GPE can be use to assess the physical functioning of the musculoskeletal system and includes 52 well-defined and standardized items within 5 main domains (posture, respiration, movement, muscle, skin). The instrument, referred to as GPE-52, registers information from the upper and lower extremities, trunk and head [131]. The examination comprises observation of posture, respiration and active movements. Range of motion (ROM), flexibility and ability to relax, are assessed by passive movements. Muscle tension and compressibility, and skin elasticity and compressibility, are assessed by manual palpation. Each of the 52 items is scored according to deviation from a predefined ideal standard, i.e. “zero”. The 15 point scale has scores ranging from - 2.3 to + 2.3 [131]. The “±” indicates “more” or “less” of a quality compared to a standard, while absolute values indicate degree

---

of dysfunction. Higher scores indicate more problems. Overall sum-score, sum-scores from the 5 main domains and from 13 sub-domains can be derived, giving a more comprehensive picture of the patient's functional problems by indicating the degree of problems "globally" or "locally" [131].

Satisfactory psychometric properties are demonstrated in patients with long-lasting musculoskeletal pain [131]. Inter-tester reliability has previously been reported as satisfactory [131]. Localization and extent of muscular dysfunctions have been demonstrated in sub-groups of patients [132]. Norms for groups of patients and healthy persons are available [133]. The scale discriminates between patients and healthy persons [133] and sub-groups of patients [133]. High GPE-52 scores are associated with more extensive impairments physically as well as psychologically in patients with long-lasting musculoskeletal pain [134]. The scale has been found sensitive and responsive to clinical important change [135].

## **Procedures**

*Papers I and II:* A booklet containing a set of questionnaires, among them the VSS-SF(NV), was sent to the patients with a pre-paid envelope for return of documents. Following the first send-out, 423 (52 %) forms were returned. Non-responders were sent up to 2 reminders after which a total of 549 (67 %) responded. Inspection of the forms indicated missing items in 86 of the returned forms. Data could be imputed in 40 forms, while the remaining 46 forms were discarded. These 46 responders did not differ from the rest of Sample 1 on background information (age, sex and diagnosis). Following imputation, 503 (61 %) had a complete set of data on the VSS-SF(NV).

*Papers III and IV:* Assessment by physiotherapists included gait tests and examination of the musculoskeletal system. Assessment was carried out according to a

standardized protocol pre- and post-intervention. One physiotherapist managed gait testing and the questionnaires, the other the clinical examination. The test-session lasted between 1 to 1.5 hours.

*Gait test by accelerometry:* Care was taken to avoid unnecessary movement between the accelerometers and the body in order to reduce the influence of the static gravity component. The 2 synchronized accelerometers fitted snugly to the body at the lower and upper trunk by fixation belts. The distance between the lower and upper accelerometers was registered and positioning of the devices was adjusted to retain the same distance between the instruments on both occasions.

Patients walked along an 8.5 m long marked path. Instructions were given [119] according to a standardized protocol: 1) “Walk slowly as if you were waiting at a bus stop”. 2) “Walk at your normal, comfortable speed”. 3) “Walk as fast as you can safely, without running”. Time was registered during steady state walking for the middle 4.3 m by photoelectric cells connected to a computerized stop-watch. Six sequences (forward and return, times 3) of data were generated by each patient. The path areas before and after registration were used to adjust speed. The patients walked back and forth with a short interval between walks, patients had the opportunity to sit down. Six sequences of data was collected for each patient. Registration was preceded by a pre-test walk for familiarization. Patients walked barefoot or with shoes at pre- and post-intervention tests. Calibration of the accelerometers against gravity [117] was carried out on a horizontal surface before each test session according to standardized procedures (**Paper III**).

2) *Filling in a booklet of questionnaires* including the VSS-SF(NV), was done on site by the patients without assistance.

---

3) *Musculoskeletal examination* according to the GPE-52. The examination was according to a manual, and done by the same therapist on all the patients. The therapist was involved in the clinical examination only (**Paper IV**).

**Test-retest reliability (Papers I, III):** Patients were asked to fill in the questionnaires at home 48 hours after the original testing, and return it by mail in a pre-stamped envelope (**Paper I**). Gait test by accelerometry was repeated approximately 45 minutes after the first gait test (**Paper III**).

**Intervention (Papers III, IV):** The MVRT programme was given as group treatment (5-9 participants starting in each group) each sessions lasting 1.5 hour (60 minutes exercises, 30 minutes dialog/discussion) once weekly over 9 weeks. The programme was complemented by a home training programme. A third physiotherapist was responsible for running the intervention and was only involved in this part of the project.

## Statistical analyses

Score distribution on the main outcome measures was inspected by Q-Q plots and by comparison of mean and median scores, and approximate normality could be assumed. Demographic data were reported as mean, standard deviation (SD), confidence interval (CI), median and interquartile range (IQR), according to data.

**Paper I:** The underlying structure of the VSS-SF(NV) was examined by exploratory factor analysis (EFA), while internal consistency, was examined by Cronbach's alpha ( $\alpha$ ). Receiver Operating Characteristic (ROC) curves and the Area Under the Curve (AUC) were used to explore the scale's ability to discriminate between sub-groups of patients in Sample 1. Pearson's correlation was used to explore the construct validity, and test-retest reliability was examined using intraclass correlation coefficients (ICC 1,1<sub>agreement</sub>) in Sample 2 in the thesis. The within-subject standard deviation ( $S_w$ ) based on the analysis of variance

(ANOVA), was used to calculate the smallest detectable difference (SDD) at an individual level as  $(1.96 \times \sqrt{2} \times S_w)$  is presented in the thesis (Table 2). Analyses were based on data from Sample 2.

**Paper II:** The one-way ANOVA model with Bonferroni's post-hoc test was used to compare differences in symptom scores between diagnostic groups in Sample 1. A two-way ANOVA model was used to analyse the impact of 2 independent variables, dizziness (2 categories), and diagnosis (6 categories) on symptom severity, and whether symptom score differed in dizzy and not dizzy patients, and if there was an interacting effect between dizziness and diagnosis. The general linear model (GLM) procedure of SPSS [136] with the repeated measures option, was applied to explore the impact and possible interacting effect of dizziness and diagnosis on the symptom sub-scales, and the 2 independent variables (dizziness and diagnosis) were further used as grouping factors with sub-scales as repeated factor. Simple (unadjusted) and multiple (adjusted) logistic regression analyses were used to identify possible predictors of long-term development of symptoms. Non-normal continuous data was explored by the Kruskal-Wallis test, while Pearson's chi-square statistic examined differences between groups in dichotomous data.

**Paper III:** Gait velocity, cadence and step-length were calculated from accelerometry data in Sample 2. A quadratic relation between many gait variables and walking speed has been demonstrated in relation to walking, and quadratic curve estimates of such relations can be computed for a subject when data from at least 3 different walking velocities are available [113]. From the individual's curve estimate, a point estimate could be calculated at a normalised walking speed when actual walking speeds were self-administered by the subject. Analysis of the RMS trunk accelerations, cadence, and step-length were done at a normalised velocity of 1.2 m/sec, which was identical to the mean preferred walking speed, and within the range of speed for all included patients before and after intervention. Data processing was

---

carried out in Matlab versions 6.5 and 7.1 and Excel for Windows, version 2000<sup>XP</sup> in line with previous work [113]. Paired samples t-tests were used to explore differences in mean acceleration values and mean symptom scores.

**Paper IV:** Paired samples t-tests were used to explore differences in mean scores on the GPE-52 and in mean symptom scores. Wilcoxon's signed rank test was used to compare change in GPE-52 items.

To explore associations between the outcome measures, Pearson's bivariate product moment correlation ( $r$ ) was used [81] on change scores of the variables. To compare the measures sensitivity to change, the unitless standardized response mean (SRM) was examined [137]. The SRM was calculated by dividing change scores by the SD of the change score. As sample size was comparable, it can be inferred that the largest SRM gives the most significant change [137].

Statistical significance was set at  $p \leq 0.05$  for all studies. Analyses were done by the statistical programme SPSS Windows versions 13-16.

### **Comment on the use of parametric statistics**

The use of parametric statistics on sum-scores originating from ordinal data such as seen in the VSS-SF and the GPE-52 examination, is controversial [81]. The discussion is an ongoing debate with strong opinions on either side, and beyond the scope of this thesis. However, both instruments are constructed with numerals assigned to the underlying ordinal scales and take on the assumption that the underlying concept in each successive category increases or decreases in line with the assigned number [107]. Scaling properties are not a requirement for use of specific statistical procedures as long as assumption of normality, independence and homogeneity are met [81]. Parametric statistics has been claimed to be fairly robust in analysis of ordinal data [138], and a pragmatic approach is that data can be analyzed as if on

interval level without introducing severe bias, unless distribution is severely skewed [81,107].

The sum-scores of the VSS-SF(NV) and sub-scales in Samples 1 and 2, as well as the sum-scores of the GPE-52 in Sample 2, met the assumption of normality. The large N in Sample 1 makes this sample less vulnerable for skewed distribution [139], but normal distribution was also demonstrated in the diagnostic sub-groups of Sample 1. In Sample 2, normal distribution on the GPE-52 was seen within the domains and sub-domains, but not on the item level, and non-parametric statistics were therefore used in analyses of data at this level. Data obtained from the accelerometers are at the ratio level.



## Synopsis of papers

### **Paper I: Psychometric properties of the Vertigo Symptom Scale - Short Form**

The aim of this study was to translate, adapt and explore the measurement properties of the VSS-SF for use in Norway. The factor structure, the internal consistency, and discriminative ability were examined using data from Sample 1 (n = 503). Construct validity and test-retest reliability were explored by a sub-sample (n = 28) of Sample 2. EFA revealed 2 factors relating to the vertigo-balance and autonomic-anxiety dimensions of dizziness (**Figure 1, Table 2**). Internal consistency ( $\alpha$ ) for the total and sub-scales was satisfactory ( $> 0.80$ ). Construct validity was explored by examining the VSS-V's relation to a "gold standard", i.e. balance in the standing position represented by sway measured by static platform posturography. Moderate correlation ( $r = 0.52$ ;  $p < 0.01$ ) was found between VSS-V and sway, while no correlation was demonstrated between sway and the VSS-A, validating the VSS-V as a measure of balance. The ability to discriminate between dizzy and not dizzy people (**Figure 2, Table 3**), was stable and satisfactory for the VSS-SF as well as for the sub-scales (AUC 0.77 - 0.91), and cut-off values were identified (VSS-SF: 6.5, VSS-V: 2.5 VSS-A: 3.5) (**Table 3**). The instrument did not discriminate between vestibular and non-vestibular types of dizziness. Satisfactory test-retest reliability (**Table 4**) was demonstrated for the total scale and the sub-scales (ICCs 0.88 - 0.90). The measurement properties of the VSS-SF (NV) seemed to be satisfactory.

## **Paper II: Long-term symptoms in dizzy patients examined in a university clinic**

The study aimed to investigate the long-term course of symptom development according to the VSS-SF(NV) by combining survey data with existing medical chart data registered in Sample 1 (N = 503) around 4.5 years prior to the survey. The sample's mean age was around 50 years at the time of the survey, and women were slightly overrepresented. Dividing the sample into 6 diagnostic groups, showed differences with respect to symptom duration, sway (path length) and neck pain (**Table 1**). Severe problems with dizziness, indicated by scores  $\geq 12$  VSS-SF(NV) points, were seen in the total group, and in 5 sub-groups (**Table 2**). Vertigo/balance- and autonomic/anxiety-related symptoms were present in all groups (**Table 2**). Split into *currently dizzy* (74 %) and *currently not dizzy*, the first group scored 17.2 VSS-SF(NV) points compared to a score of 5.0 points in the latter. Although symptoms related both to vertigo/balance *and* autonomic/anxiety, balance related problems dominated among the *currently dizzy* (**Table 3**). More than half (59 %) reported neck pain at the time of the survey. Symptom duration and neck pain predicted dizziness (**Table 5**). Balance related dizziness was also predicted by these, in addition to sway and age. Neck pain was the only predictor of autonomic/anxiety related dizziness. The medical diagnoses itself had no particular influence, and it was not possible to distinguish between dizziness of vestibular and non-vestibular origin. The persistence and severity of dizziness may raise questions whether more efforts should be directed at identifying the type of dizziness, rather than towards diagnostic belonging. It is suggested that questionnaire-based evaluations could assist in this process, and provide a better basis for specific rehabilitation. The implication of the findings may raise questions with respect to treatment and referral routines.

---

### **Paper III: Improved attenuation of trunk acceleration during walking following intervention in patients with unilateral vestibular deficiencies**

The aim of the study was to explore attenuation at the trunk in patients with unilateral vestibular deficiencies (UVD) during ambulation assuming attenuation to be compromised. Adequate attenuation of trunk accelerations to reduce the impact of body oscillations on the head is critical in controlling the head as a stable platform for perception of sensorimotor information. Further, it was an aim to see if attenuation at the trunk could be improved following intervention by the MVRT programme. The sub-sample of Sample 2 (**Table 1**) consisted of 21 patients (mean age: 51 years, women: 57%) with complaints of dizziness that had lasted on average 2.5 years at the start of the project. Patients were tested before and after the intervention. Body mounted accelerometers at lower and upper trunk registered linear trunk accelerations during unconstrained walking. Symptoms were registered by the VSS-SF(NV). Significantly higher accelerations at the lower compared to the upper trunk was seen both before and after intervention. More effective attenuation was found following intervention. Increased accelerations at the lower and decreased accelerations at the upper trunk along the antero-posterior ( $p = 0.05$ ) and medio-lateral axes ( $p < 0.01$ ) indicated improved attenuation (**Table 3**). After controlling for walking speed, cadence was reduced ( $p = 0.01$ ) and step-length increased ( $p = 0.01$ ). Self-reported balance on the VSS-SF(NV) improved ( $p = 0.05$ ). Increased stability of the upper trunk associated with increased mobility of the lower trunk during walking, is compatible with improved head control as a basis for perception of sensorimotor information and facilitating balance control. The use of accelerometry may be useful for identification of balance control during walking in UVD patients.

## **Paper IV: Physical findings in patients with dizziness undergoing a group exercise programme**

The aim of the study was to examine localization and extent of physical manifestation of muscular dysfunctions in 32 patients (Sample 2) with long-lasting dizziness by the GPE-52 (**Table 3**). It was further an aim to investigate whether the instrument detected changes in the musculoskeletal system following completion of the MVRT programme. Symptoms of dizziness were registered by the VSS-SF(NV). Pain was registered by a pain drawing. Findings prior to intervention demonstrated musculoskeletal dysfunctions by the GPE-52 sum-scores (**Table 4**) as compared to previous findings in healthy persons. Dysfunctions were related to posture, indicated by a flexed head position. Restricted respiration and movements, the latter indicated by reduced flexibility and ability to relax, and restricted ROM in the upper trunk, were also observed (**Table 4**). All (n = 24), but 3 of those who filled in the pain drawing reported pain. Of these, 8 patients (33 %) reported pain located in the upper body only, 7 patients had pain in the upper and lower body. Severe dizziness ( $\geq 12$  points) was registered by the VSS-SF(NV) (**Table 5**). After intervention, improvement in muscular function was seen according to the GPE-52 score ( $p < 0.001$ ) (**Table 4**), and changes were particularly found in respiration and in movements of the neck and upper trunk. Self-reported balance did also improve ( $p < 0.05$ ) (**Table 5**). The study showed that musculoskeletal dysfunctions were common in our patients and that the MVRT improved respiration and movements in the upper body as well as self-reported balance.

## Discussion

### Methodological issues

#### Papers I, II: Design and material

By combining designs, the measurement properties of the VSS-SF(NV) and current state of patients could be explored in a cost-effective and relatively easy manner [81,82]. The designs (survey, archival) are however, vulnerable to low response rate and missing information [83,140], which may challenge study validity. Response rate could have been influenced negatively by seasonal factors, and posted reminders were used to increase this. To further increase the response rate, imputation of missing items was undertaken where possible resulting in 503 forms with complete set of data. Questions can be raised whether answers from non-responders would have had an impact on the results [82]. There is no simple answer to this as it requires asking the non-responders directly, which has ethical as well as legal implications. This was not an issue, and to the extent that the question could be explored by existing data (**Paper II**), it can be argued that this was unlikely.

Missing information from the medical charts was seen in registrations on posturography and on date of debut. The 5 % missing from the posturography registrations corresponded to 2 periods where the platform was unavailable. Duration of symptoms could not be calculated for approximately 10 % of the sample. The greatest percentage was, as expected, found in the vestibular schwannoma group, since the condition typically develops gradually. Missing information on medical charts resulted in varying sample size (**Paper II, Table 1**), which still remains a large sample.

Sample 1 can be classified as a sample of convenience [81] expected to represent the entire population [81]. Potential participants might however have been missed through the

diagnostic process. In most of the included groups, lack of specific symptoms and definite criteria [50,141] complicate the diagnostic process. The majority (62 %) of our patients had a vestibular disorder (Table 1). The rest had similar symptoms, but lack of specific organic findings classified them in the non-vestibular category. In about 1 of 7 cases, the cause of dizziness is not established [142,143]. This does not necessarily exclude vestibular causes [9,13,14,89]. The mixture of vestibular and non-vestibular categories is common in specialist clinics [50,85,89,143], the percentage of vestibular categories varies from 44 % to 65 % [89,142,143]. The sample was drawn from specialist institutions, and selection bias could be a problem. Symptoms are highly personal experiences [144], and these patients may present with atypical, and/or more complicated symptoms than that seen in other settings.

A response rate of 61 % can be considered acceptable in a postal survey [145], and particularly in view of sample size [82]. Larger samples are suggested to be more representative of the population than smaller samples [82]. The sample size and response rate of the present study should be sufficient to allow valid conclusions.

### **Papers III, IV: Design and material**

In this quasi-experimental longitudinal design, referred to as a within-group design [81] as a single group is tested before and after intervention. The design is considered to be a weak design, where patients act as their own control.

Sample 2 consisted of 4 cohorts making up a sample of convenience. Inclusion was by careful reading of journal notes in view of the defined inclusion and exclusion criteria. The process resulted in a fairly homogenous sample as the condition most likely originally was caused by vestibular neuritis. Age as inclusion criterion was not strictly followed. One older patient (73 years) was invited by a mistake and included after the physiotherapy examination. The examination did not reveal any other health complaints than those related

to dizziness. It is possible that age as inclusion criterion should have been less strict, and examination should rather have guided the inclusion. Inclusion further comprised consideration of addresses. As the clinic served the whole country, this was a necessary pre-requirement to make sure that participation in intervention was practically possible. Several potentially suitable patients were excluded for geographical reason, and no information is available on these patients. Active use of the defined criteria, can be said to add some strength to the rather weak sampling method, but care should be exerted when drawing conclusions [81,146].

## **Issues of validity**

Validity comprises several dimensions. A valid instrument should identify problems and give meaningful information [81], and this is the focus for the discussions in the following sections. As the measurement properties of the VSS-SF were explored for the first time in this Norwegian version, the instrument is discussed against recently suggested quality criteria for health status measurements [147]. The discussion then focuses on validity of findings from the main outcome measures in the respective papers.

### **Instrumental validity, Paper I, II**

*Content validity* is positively rated if aims, target population, concepts and item selection are described [147]. These elements were taken care of in relation to developing the mother instrument, the VSS [85]. The VSS-SF is derived from the VSS [23,97] and consist of subscales in line with the mother instrument (Appendix, Table 2). Care was taken that the Norwegian instrument included apparent key terms from the original scale. The content validity of the VSS-SF(NV) can thus be said to be similar to that of the mother instrument. Content validity of the VSS-SF(NV) is also strengthened by floor (9 %) and ceiling (3 %)

effects below the recommended 15 % [147]. As there is no other instrument in the Norwegian language that detects symptoms of dizziness, examination of *criterion validity* of the VSS-SF(NV) [147] was not pursued.

Homogeneity, i.e. *internal consistency* of the VSS-SF(NV), was investigated by EFA. The ratio of sample size to items included was satisfactory [147]. The factor structure of the VSS-SF had not been explored, although principle component analysis (PCA) of the long version (VSS) had been examined [85,89-91]. Differences between the various versions of the scale, as well as differences in the analytic approach, complicate direct comparison (**Paper I, Table 2**). PCA could result in inflated component loadings [148,149] altering the nature and interpretation of the construct [149], but this was not found. The sub-scales of the VSS-SF(NV) were in concordance with the original scales (**Paper I, Table 2**). The scale with sub-scales can probably be considered to be robust. *Internal consistency* was also explored by Cronbach's alpha as recommended [147]. Both the total and sub-scales had alpha-values above acceptable limits ( $> 0.70$ ) [147].

To examine *construct validity* of the VSS-V, this sub-scale was correlated with a measure on balance in the standing position (static posturography, sway registration). Satisfactory ( $r = 0.52$ ) correlation was observed taking the different type of measures into consideration [150]: self-report and physical performance. The number of participants ( $n = 28$ ) was below that ( $n = 50$ ) recommended [147], making the estimate less robust than desirable. Construct validity [147] should be tested by several hypotheses, and at least 75 % should be in concordance with suggestions. Only one hypothesis was tested in the present study, but assumptions of low correlation ( $p = 0.30$ ), between VSS-A and balance in standing, and between the sub-scales ( $p = 0.41$ ) were confirmed, supporting the tested hypothesis.



Parametric statistics could be used, and the ICC was used as an indicator of *reliability* as recommended [147]. Reliability was satisfactory ( $ICC_{1,1\text{agreement}} > 0.70$ ) (**Paper I, Table 4**), although the number of participants ( $n = 28$ ) was below recommendations ( $n = 50$ ) [147]. Filling in forms was part of an extensive test battery, the risk for recall bias was considered small and no change in the clinical situation was expected. The test-retest interval can thus be justified [147].

In line with recommendations [147], agreement is reported as measurement error at an individual level ( $SDD_{\text{individual}}$ ) (Table 2).

**Table 2: Absolute reliability ( $S_w$ ), and smallest detectable difference (SDD) of the Norwegian version of the Vertigo Symptom Scale-Short Form (VSS-SF(NV)) and sub-scales (N = 28)**

| Scale (scale range) | $S_w$ | SDD |
|---------------------|-------|-----|
| VSS-SF(NV) (0-60)   | 2.8   | 7.8 |
| VSS-V (0-32)        | 2.0   | 5.5 |
| VSS-A (0-28)        | 1.4   | 3.9 |

VSS-V: vertigo/balance sub-scale, VSS-A: autonomic/anxiety sub-scale

No definite value exists regarding the size of measurement errors [147]. An SDD of 8 VSS-SF(NV) points (Table 2) to claim true change on the overall scale, is probably more than what would be considered clinically important by patients with long lasting dizziness, as well as by clinicians. Similar arguments can be put forward for the SDDs of the sub-scales. A larger sample ( $n = 50$ ) as suggested to explore this property [147], might have resulted in smaller SDs and consequently smaller SDDs. Terwee and collaborators [147] suggest to calculate the SDD for groups based on the  $SDD_{\text{individual}}$  ( $SDD_{\text{group}} = SDD_{\text{individual}}/\sqrt{n}$ ). Based on this, an  $SDD_{\text{group}}$  of 1.5 VSS-SF(NV) points is found. This is lower than the previously

defined 3 VSS-SF points [23,67]. There are no previous values reported on clinically significant changes for the sub-scales. Our results could support that a clinically significant change in the region of 2-3 points on the total scale is feasible in groups of patients with long-lasting dizziness, even though the value at the individual level is somewhat high.

The measurement properties of the VSS-SF(NV) were explored in relevant target groups and conducted in a setting similar to future use in line with the recommendations [147]. Sample size can be said to be acceptable taking into consideration that the suggestions are opinion based [147]. Rating of the 9 factors on the VSS-SF(NV) and on the original short form VSS-SF, is presented (Table 3) according to Terwee et al's suggestions [147]. Positive rating is given to 7 of the factors for the VSS-SF(NV). Information is not available for 1 factor (responsiveness), while it can be argued that evaluation of criterion validity is not applicable as VSS-SF(NV) represents the gold standard.

**Table 3: Quality criteria for measurement properties of the VSS-SF(NV) and VSS-SF based on Terwee et al.<sup>141</sup>**

| Scale version | Content validity | Internal consistency | Criterion validity | Construct validity | Reproducibility (Agreement) | Reliability | Floor ceiling effects | Responsiveness | Interpretability |
|---------------|------------------|----------------------|--------------------|--------------------|-----------------------------|-------------|-----------------------|----------------|------------------|
| VSS-SF (NV)   | +                | +                    |                    | +                  | +                           | +           | +                     | ?              | +                |
| VSS-SF        | +                | 0                    |                    |                    |                             |             |                       | +              |                  |

VSS-SF(NV): Vertigo symptom scale - short form, Norwegian version; VSS-SF: Vertigo symptom scale - short form

Scoring: (+) = positive rating, (0) = indeterminate rating, (-) = negative rating, (?) = no information available

Acceptable study designs were used to explore the VSS-SF(NV) as a discriminative instrument [147], and the instrument exhibited a high degree of reliability. Identified cut-

---

points for dizzy/not dizzy (**Paper I, Table 3**), and scores for various diagnostic subgroups (**Paper II, Table 3**) assist in the interpretation of the scale. This is complemented by cut-point regarding severity ( $\geq 12$  VSS-SF points) reported in the original version [67]. An acceptable design [147] was also used to explore sensitivity to change in the VSS-SF(NV), and satisfactory level of agreement [147] was found. Study of responsiveness was not undertaken in the Norwegian version. However, findings in studies on the original VSS-SF [23,67], and in another translated version [104] indicate a responsive scale.

### **Instrumental validity, Paper III**

Satisfactory test-retest reliability ( $> 0.70$ ) was found on both accelerometers (**Table 1**). Satisfactory test-retest reliability has also been reported by others in relation to gait [115,120,125,151]. Excellent precision and accuracy have previously been reported for the 2 synchronized accelerometers [117].

According to Kavanagh et al. [120] the risk for variability in reapplication of accelerometers is small. The procedure for positioning the instruments secured the same distance between the instruments ( $p = 0.25$ ) over time. By fitting the accelerometers to be in close contact with the body at the lower and upper trunk, unnecessary movement between the accelerometers and the body was avoided. This reduced the influence of the static gravity component during testing. Variability could also have been caused by systematic shift in performance. To familiarize with the situation, habituation walks were performed prior to registration, and no training to task effect was observed (**Table 1**) between test and retest [115].

Normalisation of velocity prior to analysis allowed comparison of speed dependant variables across patients and test situations [113]. However, a common range of velocities

must be available and care must be taken to secure that the range of velocities demonstrated by each subject includes the chosen normalized speed. Although instructions and pre-testing was undertaken to limit the risk of non-overlapping ranges, the results from one patient had to be omitted because velocity was outside the range of the rest of the group. There is also a risk for technical failure in studies like this, and the results from two patients had to be omitted for this reason. How this might have influenced results is not known.

The psychometrically sound instrument and the standardized test procedures reduce external factors influence on the results. The analytic procedures made it possible to compare the results across patients over time.

### **Instrumental validity, Paper IV**

The GPE-52 has been established as a psychometrically sound instrument [131], small measurement errors and high inter-tester reliability has been found. The GPE-52 is dependent on observations and interpretation of qualities in body function and structures. The same therapist examined all the patients which could introduce bias in scoring in several ways. To minimize the risk for variability and subjectivity in scoring [152], calibration between colleagues was undertaken on a regular basis. Based on the design, the therapist knew that all the patients examined post-intervention had participated in the programme. This could influence interpretation of the findings [81]. Care was taken not to have pre-intervention results available at post-intervention testing to minimize this effect. Care was also taken not to exhaust the patients as patients' motivation and efforts, fatigue and lack of concentration, can influence the examination and results [81], but no-one has made any comments to this extent. There is nothing indicating that scores are influenced systematically.

---

The GPE-52 is founded on the NPPT tradition [76]. As a measuring instrument, the GPE-52 reflects here-and-now observation in a standardized and systematic manner. The NPPT assumes that the versatile body, given the opportunity, would change. And further, assessment represents such an opportunity. These assumptions imply that capturing the here-and-now status, is invalid as the body is in a position to change. This is a discussion beyond the present work. Systemization and standardization is necessary in order to compare groups and capture change over time.

The GPE-52 fulfils the requirements for being a reliable and valid measure according to Rothstein [81]. As a composite measures it is more reliable [107,153] than isolated tests with respect to capturing function.

### **Validity of findings from self-reports, Papers II, III, IV**

Validity raises questions whether the VSS-SF(NV) has given meaningful information. As expected, patients claiming current dizziness had the highest scores (**Paper IV, Table 5, Paper II, Table 3**). Scores among those not being dizzy (**Paper II, Table 3**) were lower confirming our expectations. In the dizzy group (Table 1) scores were above the defined ( $\geq 12$  VSS-SF points) severity limit, but severe dizziness defined at this level on a scale ranging 0–60, could be questioned. The definition must be interpreted in view of the condition, i.e. dizziness of long duration, but the limit between scores in patients with acute versus long-lasting dizziness, should be explored.

Standardization of information by the VSS-SF(NV) may challenge validity as symptoms reflect private experiences [13,20]. Interpretation of symptoms are influenced by perceived sensations, whether it is conceived as chief complaint, by judgement relating to the origin of symptoms, and by the importance and meaning given to the sensations [154]. The latter may have changed several times in view of the duration of the condition, and the

reports may exaggerate morbidity, claiming symptoms that are not really present, as well as increased severity [144]. The best way to pass on this type of information is voluntarily [144] and by use of own words [155], not possible in a standardized instrument like the VSS-SF(NV).

Symptoms relating to anxiety/depression, which are common in patients with persistent dizziness [98], are not captured by the VSS-SF(NV). This might be considered a shortcoming in this work. It has been suggested that focusing on these dimensions might lead to denial [98]. It can be argued that all versions of the VSS instrument capture vertigo/balance and autonomic/anxiety, which could give sufficient information on the type of problem the patient is facing. The physiotherapists' professional knowledge is first and foremost directed towards physical aspects of a condition. If symptoms mainly relate to the anxiety dimension, assistance from other professionals should be considered.

Another dimension that could be said to be lacking relates to QoL. The Dizziness Handicap Inventory (DHI) [156], the UCLA Dizziness Questionnaire (UCLA –DQ) [157], as well as the Medical Outcome Study Short-Form Health Survey Questionnaire (SF-36) [158] are all QoL measures, frequently used in patients with dizziness from a variety of causes [45,159-166]. The psychometric properties of the DHI and UCLA–DQ are however questioned [167,168]. QoL represents a separate, distinct dimension from symptoms. QoL is a social construct associated with feelings of disability, and interpreted in view of the individual's expected role in society [153]. Self-reports on QoL, may reflect adapted lifestyles disguising underlying problems [169]. On the other hand, capitalising on different types of measures could have expanded the information obtained. Although not reported here, QoL instruments were used in the project.

Self-reports such as the VSS-SF(NV) are considered the gold standard [170] when symptoms are focused. Information by the instrument is of value as it extends uncontaminated information on symptoms of dizziness, and we should trust the patient to submit their true perception implying that findings on the VSS-SF(NV) are valid.

### **Validity of findings from balance in gait, Paper III**

Patients with dizziness typically report problems related to unsteadiness during ambulation. Poor trunk control [171], reduced trunk motion [172] and excessive head movements compared to healthy persons [173,174] have been described in relation to walking. It is possible that the normal trunk-head stabilisation processes are disturbed resulting in problems with balance and visual stability [30]. Attenuation of trunk accelerations is associated with the control of balance [109,110,175,176]. Therefore, exploring trunk accelerations in relation to gait holds a potential to reveal underlying control strategies.

Our findings showed attenuation patterns in a cranial direction similar to those of healthy [124] at pre- and post-intervention. By comparing the attenuation pattern pre-intervention to that found post-intervention, it could be inferred that attenuation had been compromised. The change, resulting in a more flexible lower, and more stable upper trunk, might well reflect improved head control [110] facilitating balance control. Changes related to RMS acceleration in the horizontal plane imply that modulation of horizontal acceleration is not only linked to shock absorption, but also to aspects of balance control by stabilizing the head-on-trunk as a platform relative to which vestibular and visual information is processed [110]. It is not unlikely that this important function of the vestibular system is impaired in UVD patients. Limitation with respect to stabilization in gait, has been reported in this group of patients [172-174]. The greatest change was seen along the ML axis and the ability to attenuate acceleration along this axis has previously been suggested to be of

particular importance for balance control [119,177]. The pre-intervention attenuation pattern could have influenced head stability and consequently balance control [30,178].

Examination of balance in the standing position is the traditional way to measure balance. Several types of platform exist for this purpose, a categorisation suggested by Bronstein [179] divides the traditional approach into *static posturography* where the patient stands quietly on the platform as opposed to *dynamic posturography* when additional balance perturbations or stimuli are added [179]. Balance in standing and balance during walking, requires different strategies. Measuring balance in the standing position may leave faulty impressions of adequate compensation due to underloading and hide functional problems [180,181]. It is possible that balance in the standing position is satisfactory as part of a diagnostic process, but questions could be raised if these methods are adequate as indicator for functional change in long-lasting dizziness.

Examination of balance in patients with long-lasting dizziness should be performed in challenging tasks such as gait. Methods by accelerometry might however, be unobtainable in most clinical practices. Currently there is no accepted clinical “gold standard” [182]. The Dynamic Gait Index (DGI) [183] and a modified version, the Functional Gait Assessment (FGA) [182], have been used with vestibular deficient patients. Both tests show some methodological problems [182]. Testing the DGI scale [184] on a Norwegian group of patients, confirmed the presence of a ceiling effect, as well problems with scoring. In a recent project [185], elements from 6 different clinical tests were combined in a test battery to identify deficiencies in underlying balance control systems. According to the investigators [185], methodological issues as well as the usefulness of the test battery needs to be further examined.



---

Gait analysis is a method that gains validity by revealing functional dimensions of balance control. These aspects have to our knowledge, previously not been examined in patients with vestibular disorders. The obtained information can assist in understanding how balance is disturbed in these patients. It is possible that trunk accelerations registered in even more challenging environmental settings than the flat floor of the present study, would have given more information.

### **Validity of findings from the musculoskeletal system, Paper IV**

Inclusion of the GPE-52 measure [135] was based on face and content validity in view of the problems presented by the patients. According to the tradition, NPPT [76], the body is an integrated unit. Transferred to patients in our study: impairments in vestibular function may impact the whole body. Over time this may result in bodily compensatory strategies which can be manifested as changes in the musculoskeletal system [131].

Our clinical experience prior to starting the present work, indicated that patients with dizziness presented with alteration in posture, pain, tense muscles and restricted ROM particularly in the upper trunk region. Existence of musculoskeletal problems was confirmed in the clinical examination. Scores higher than those of healthy persons and in line with other patient groups [133] were documented prior to intervention (**Table 4**). Improvement was seen following intervention (**Table 4**) indicating that the GPE-52 total and domain sum-score give meaningful information on physical signs from the musculoskeletal system also in our group of patients.

It is difficult to relate our findings to other reports. With some exception [48,186], symptoms as well as signs from the musculoskeletal system are seldom presented although assessment of the system is described as important [24,187,188]. The suggested assessments [24,187,188] present as fragmented (active and passive movements, muscle tests of the lower

extremities, posture and alignment, neck), similar to assessment of orthopedic problems [153]. In a functional perspective, validity of findings from this type of examination, can be questioned [153]. It could be argued that the GPE-52 also examines parts. However, individual tests are not interpreted in isolation, but added to form summary scales before relating the scores to function.

The GPE-52 instrument has not previously been used in patients with vestibular disorders, but it can be concluded that meaningful information regarding the musculoskeletal system was obtained, also in our patients.

## **Outcome measures**

### **Outcome measures in view of ICF**

The VSS-SF(NV) and the GPE-52 can be identified as health status measures [189]. The VSS-SF(NV) can be further classified as a patient oriented and/or condition specific instrument, the GPE-52 as clinical and/or generic [189]. The purpose of health status measures is to describe the burden of disease [190] by use of summary scales to give an overall level of functioning [191]. These are characteristics of the VSS-SF(NV) and the GPE-52. Trunk acceleration associated with gait as a measure, represents a different category. It depicts characteristics of gait and captures physical performance. Restriction in the capacity to perform, can also describe the burden of a disease. Using health status measures allow comparison across groups, interventions and times.

There are suggestions [189,191] that the ICF classification system could serve as a connecting framework between interventions and outcome measures, to facilitate selection of outcome measures in relation to aims. This can be done by so-called linking rules which link meaningful concepts observed in items of health measures, to the most fitting ICF categories

---

within the components, i.e. *body structure and function, activity and participation*. The rules do not differentiate between the concepts in the component *activity and participation* if items that contain meaningful concepts addresses both aspects of this component [189]. As part of linking the health measures to ICF, scaling systems should also be adjusted and standardized [191]. No attempts are made at using the linking rules per se in this work, but the included measures are discussed in relation to the components of the ICF.

At the item level, both the VSS-SF(NV) and the GPE-52 relate to impairment in *body structure and function* [25] by focusing on symptoms stemming from reduced vestibular function, and on elements like restricted ROM and strength of muscles, respectively. It could be argued that some items in the balance sub-scale of the VSS-SF(NV) and in the GPE domains, link to the component *activities and participation* [189]. However the VSS-SF(NV) and the GPE-52 are intended to make up various summary scales to reflect the burden of the disease, implicit higher scores indicate larger impairments in the present scales. As summary scales it could be argued that they go beyond the impairment level, and relate to the activity and participation component by indicating the capability to perform. Trunk accelerations are associated with body oscillations which in the present work are captured in relation to gait. The accelerometer as such, registers impairment in body structure and functions [25]. However, information can be obtained on gait at the functional level, implying a link to the component activity and participation. Although focus can be set on gait, the underlying element targeted, is balance. A shortcoming of ICF is the lack of coding a construct like balance [189,190] an important dimension in the present work and in physiotherapy in general.

A health measure is composed of items making up construct/sub-constructs which relate to each other in specific manners to create summary scale(s). Reliability and validity are issues that can be raised if items, as part of a summary scale, are recoded to form new

scales, and care should be taken [190] to reduce the risk for measurement errors in assigning codes from one to another system.

Aims of the present intervention (MVRT) were directed at improving dizziness, balance and musculoskeletal status. Inclusion of the presented outcome measures was guided by the aims, and it can be argued that the measures are acceptable as such.

### **Association between the outcome measures**

The included measures were intended to complement each other in addressing symptoms and signs facing patients with long-lasting dizziness. In this case we would expect no association between the instruments, which was examined by correlation analyses.

**Table 4: Pearson's correlation (r) and level of significance (p) between change scores by accelerometry, VSS-SF(NV), and the GPE-52**

|             | A-P axis          | M-L axis                  | V axis | VSS-SF(NV)              | VSS-V                   | VSS-A                   |
|-------------|-------------------|---------------------------|--------|-------------------------|-------------------------|-------------------------|
| A-P axis    |                   |                           |        | 0.13                    | 0.09                    | - 0.10                  |
| M-L axis    |                   |                           |        | - 0.10                  | 0.13                    | - 0.35                  |
| V axis      |                   |                           |        | - 0.19                  | - 0.29                  | 0.05                    |
| GPE-52      | 0.32              | - 0.35                    | 0.03   | 0.21                    | 0.03                    | 0.32                    |
| Posture     | - 0.18            | <b>- 0.63<sup>1</sup></b> | - 0.24 | 0.02                    | - 0.08                  | 0.14                    |
| Respiration | 0.03              | - 0.09                    | 0.31   | - 0.29                  | - 0.43 <sup>3</sup>     | 0.07                    |
| Movement    | 0.41 <sup>3</sup> | 0.03                      | 0.21   | - 0.19                  | - 0.20                  | - 0.06                  |
| Muscle      | 0.24              | - 0.12                    | - 0.17 | <b>0.85<sup>1</sup></b> | <b>0.75<sup>1</sup></b> | <b>0.47<sup>2</sup></b> |
| Skin        | - 0.08            | - 0.17                    | - 0.33 | 0.09                    | 0.04                    | 0.11                    |

<sup>1</sup> p < 0.01, <sup>2</sup> p < 0.05, <sup>3</sup> p < 0.10

Correlations: accelerometry versus VSS-SF, VSS-V, VSS-A, n = 18; accelerometry versus GPE-52, n = 18; VSS-SF, VSS-V, VSS-A versus GPE-52, n = 20

A-P axis: antero-posterior axis; M-L axis: medio-lateral axis; V axis: vertical axis

VSS-SF(NV): Vertigo Symptom Scale-Short Form, Norwegian Version

VSS-A: Autonomic/anxiety sub-scale

VSS-V: Vertigo/balance sub-scale

GPE-52: Global Physiotherapy Examination, 52 items

No significant correlations were seen between change in acceleration values, the overall measure of the GPE-52 and the VSS-SF(NV) (Table 4). Accelerometry registers body oscillations during walking, a physical characteristic of gait. Musculoskeletal dysfunction and dizziness measured by the GPE-52 and the VSS-SF respectively, can both be considered broad hypothetical constructs [107]. The measures give different types of information, and a

lack of correlation could be expected. The 0.63 correlation found between change scores on the M-L axis and the domain *posture* of the GPE-52 (Table 4) may indicate that these factors work jointly to control balance in gait. It is possible that even small alterations in posture such as that found in the present study (**Paper IV**), is important for balance control. The correlations between the domain *muscle* on the GPE-52 and the symptom-scale ranging from 0.47 – 0.85 (Table 4), could indicate that also small improvement in muscle-domain may have an impact on perception of symptoms.

The overall lack of correlations between the measures shows that they capture different dimensions. It could be argued that the combined findings reflect a more flexible and versatile body. Improved flexibility might allow adjustments according to internal and external demands in more functional manners, and thus influence balance [27]. This is also in line with the suggestions by Mulavare et al. [192] stating that the whole body contributes to balance control during locomotion. In this manner, the measures complement each other.

Comparing the instruments' sensitivity to change in line with Moe-Nilssen et al.'s recommendations [137] (Table 5), the most significant changes were found on the M-L axis of accelerometry, which is of particular importance in the control of balance [119,177], and on the global GPE-52 measures followed by the movement domain of the GPE-52. The latter result would be in line what could be expected from a clinical point of view.

**Table 5: Mean (SD) change scores, and standardized response mean (SRM) across the outcome measures**

|  | Change scores | SRM  |
|--|---------------|------|
| <b>Self-report<sup>a</sup></b>                 |               |      |
| VSS-SF(NV)                                     | 2.4 (5.8)     | 0.41 |
| VSS-V  | 2.3 (4.4)     | 0.52 |
| VSS-A  | 0.2 (3.4)     | 0.06 |
| <b>Accelerometry<sup>b</sup></b>               |               |      |
| A-P axis                                       | 0.005 (0.012) | 0.42 |
| M-L axis                                       | 0.015 (0.012) | 1.25 |
| <b>Musculoskeletal examination<sup>a</sup></b> |               |      |
| GPE-52   | 4.0 (3.0)     | 1.33 |
| Posture  | 0.2 (1.0)     | 0.20 |
| Respiration                                    | 0.9 (1.4)     | 0.64 |
| Movement                                       | 2.0 (2.0)     | 1.00 |
| Muscle   | 0.3 (1.5)     | 0.20 |
| Skin   | 0.5 (1.1)     | 0.45 |

<sup>a</sup> N = 20, <sup>b</sup> N = 21

VSS-SF(NV): Vertigo Symptom Scale, Norwegian version

VSS-V: vertigo/balance sub-scale, VSS-A: autonomic/anxiety sub-scale

A-P axis: antero-posterior axis; M-L axis: medio-lateral axis

GPE-52: Global Physiotherapy Examination, 52 items

## Main findings

### The observation study: Dizziness and pain

From the observational study (Sample 1), dizziness and the predictor neck pain (**Paper II, Table 5**) are discussed together as it might be speculated that these symptoms somehow relate and reinforce disability. This is followed by a general discussion of findings.

The severe dizziness ( $\geq 12$  VSS-SF(NV) points) in our sample, is similar to other studies from specialist [103] and primary care [23,67,97] institutions. It can be argued that

the findings are representative for patients with long-lasting dizziness regardless of setting. The relationship between dizziness and neck pain is complex. We cannot infer that pain was due to the dizziness, or the result of a separate condition. We did however, observe that there was an increase in patients reporting neck pain from 27 % at baseline (Table 1) to almost 60 % (n = 298) at the time of the survey (**Paper II**). Patients with neck pain had significantly ( $p < 0.01$ ) more severe dizziness (mean, SD: 16.6, 10.7 VSS-SF(NV) points) than those not having neck pain (mean, SD 10.0 , 9.9 VSS-SF(NV) points).

Status with respect to dizziness was somewhat surprising taking symptom duration into consideration. It is possible that our patients are among the 30 % belonging in the CVI category, left with incomplete compensation [29,34]. The CVI syndrome is characterized by sensation of disequilibrium, gait ataxia and oscillopsia. Balance related problems were identified for patients in the study (**Paper II, Table 2**). Problems in the musculoskeletal system are considered secondary to dizziness [23,24] and not part of the syndrome. Pain and stiffness in the upper and lower part of the body, have however been reported in dizzy patients [48,186], also during attacks of dizziness [186]. Musculoskeletal problems were also identified in Sample 2 (**Paper IV**). From a study on patients with cervicogenic dizziness [48] it was reported that both pain and dizziness improved with appropriate treatment. It could be speculated whether there is a closer connection between dizziness and the musculoskeletal system, and if the dysfunctioning systems (vestibular, musculoskeletal) sustain and reinforce the functional problems. Anticipation and experiences of attacks of dizziness associated with movements, institutes fear and anxiety of movements [6]. Hyper-vigilance to internal and external illness information, muscular reactivity and physical disuse, may lead to deconditioning and guarded movements [98,193], which aggravate rather than alleviate dizziness and pain symptoms. Inactivity in a wide sense prevails and uncorrected self-interpretation of symptoms could lead into the *dizzy vicious circle* sustaining and reinforcing



---

the symptoms with each new episode. Perceived threats are acknowledged by fear and conscious/unconscious avoidance strategies [6,79]. The psychosocial processes may contribute to maintain balance dysfunction.

Recent attacks of dizziness were reported by almost 60 % (Table 1). The attacks could be interpreted as signs of serious illness [6]. Diagnostic confirmation is suggested to provide authentication of a physical origin, and is a pre-requisite for psychosocial adjustment by supplying a model for future conduct and social relations [98]. When aetiology is questioned, adjustment becomes more complicated. This could be true for the non-otogenic category in our study, but it is possible that diagnosis per se is of limited value in long-lasting dizziness (**Paper II, Table 5**).

Although it is never too late to start organised rehabilitation [71], it has been shown that behavioural activities in the early days are essential for compensation [30]. We are aware that advice like “rest to get better” has been given (personal communications). This may raise questions of knowledge among health professionals regarding treatment. It also raises questions relating to timing of referral to specialist services [4,51,194] which relates to the other predictor of current dizziness: duration of complaints (**Paper II, Table 5**). There are suggestions that referral might be considered if symptoms persist and a cause has not been established within 4 to 6 weeks [195]. Considering that more than 70 % of those with complaints of dizziness are found in the working age group (Norwegian National Insurance Service, 2005), and long-term sickness absentees for this reason represents a risk for obtaining disability pension [61], early and correct advice is important. Provision of specialist physiotherapy services at primary care levels has been suggested [4], but presuppose knowledge about treatment and rehabilitation in the profession.

In the medical examination at the NCVD, which took place almost (median) 2 years after dizziness debut (**Paper II**), all patients were advised to be physically active to promote

compensation. We do not know whether they followed the advice, which is a shortcoming of the present work. For patients with long-lasting dizziness, there is probably a need for professional care by experienced physiotherapists. This was not an option for patients in Sample 1. Dynamic compensation involves the CNS, sensory behavioural substitution processes [30,34] and psychological factors [98], and it can be considered an active (re)learning process [6,29,30]. This opens for a multitude of approaches in treatment.

### **The longitudinal study: Results of the MVRT programme**

Based on the intervention study, the main findings of Paper III and IV are discussed together.

The attenuation pattern in the trunk (**Paper III, Table 3**) facilitated more functional strategies for the control of balance in gait, and was accompanied by simultaneous improvement in spatiotemporal gait parameters (**Paper III**). The overall and domain specific changes in the musculoskeletal system (**Paper IV, Table 4**), indicated a more versatile and adaptable body. The findings were supported by improvement in self-reported symptoms on balance (**Paper IV, Table 5**).

In a randomized control trial (RCT) [74,196] a programme of Tai Chi was compared with traditional VRT. The Tai Chi approach is suggested to promote overall body control by focusing on the body-mind interaction [74,196]. The approach with focus on body awareness [74,196], has similarities with the MVRT approach. The programmes were arranged as group training (10 weeks) and offered to patients with vestibulopathy of long duration. A major finding was that trunk control associated with gait was affected, and more natural trunk movements, similar to healthy persons, were observed following intervention [74,196]. This was not seen in the VRT group. The results are in line with our findings. In another randomized study [48] body awareness was part of a programme to improve posture, neck and trunk stability in patients with cervicogenic dizziness. Improved trunk stability was

---

retained in a long-term perspective (2 years) [48]. In this latter study, treatment was directed at musculoskeletal problems, rather than dizziness per se, which can also be said to be in line with our approach. It is not unlikely that sub-optimal attenuation in the trunk impact balance in patients with long-lasting vestibulopathies. It might be important to focus on the musculoskeletal system in patients with long-lasting dizziness.

Restricted respiration was identified in our patients prior to intervention, but improved following intervention (**Paper IV, Table 4**). Vestibular compensation is promoted by eye-head movements aiming at provoking dizziness. Being told to move to provoke dizziness, may represent a dilemma as it could be associated with uncomfortable sensations. Consciously or unconsciously respiratory restrictions are brought on and over time, restriction in respiration, manifest in the musculoskeletal system. Traditional adaptation and habituation exercises [64] were therefore incorporated into functional movements, and focus was on the movements, not on dizziness. This indirect focus on respiration differs from that of another non-randomized study [75], where paced breathing combined with traditional VRT programme [75], was compared with 2 other approaches. The results showed an added effect on reduction in dizziness in the paced breathing group. In another study [197], hyperventilation was found to disrupt mechanisms mediating vestibular compensation. The dilemma between respiration, dizziness and bodily reactions needs to be further explored.

The new attenuation pattern and body movements could indicate greater capacity to adapt according to internal and external demands. Improvement was seen in a small sample acting as their own controls. Although care should be exerted in drawing conclusions, our results are in line with comparable studies of stronger designs [48,74]. Changes could be associated directly with the intervention, but it is also possible that participation in the MVRT has resulted in more active everyday life styles in general, further enhancing compensation. The potential for spontaneous change is small in view of the duration of

complaints as also recognised by others [196,198], but effect of the intervention needs to be tested further in larger samples under controlled conditions.

### **The rehabilitation programme's potential to promote change**

The core element in any VRT programme is exercises provoking dizziness in a direct manner. It is possible that this might reinforce the vicious dizzy circle. Our modified programme has the potential to break the circle by focusing on bodily movements and thus more indirectly on provoking dizziness. It is acknowledged that therapeutic gain is enhanced and maintained when patients are actively involved and intrinsically motivated rather than externally manipulated [79,193]. Through movements, requirement of active involvement are fulfilled. Movements serve as a confrontational and active coping strategy that have cognitive elements performance demands attention and focus [79,193]. Movements give access to direct experience, central in development of self-efficacy [78] and the strongest input to learning. Movements may result in success: "I moved - I managed, dizziness was not too bad", enhancing feelings of *taking control* [80], in which case it is easy to try again. However, negative experiences could sustain anxiety and fear of provoking dizziness, retaining the passive life styles. Organised sessions run by a skilled physiotherapist who assists in reflection and interpretation of the negative signals, who can coach the patients into trying again, is probably crucial to replace avoidance by confrontation.

Organization in groups enhanced the indirect learning process [78] by giving emotional support and the opportunity to observe and discuss experiences with fellow patients. This way of thinking was used in the original approach by Cawthorne and Cooksey [2]. The group setting, created more "noisy" environments, mimicking everyday settings. It is well known that these settings are frequently avoided by dizzy patients as stimuli can be overwhelming.

As a consequence of impairment, patients in our study were unable to perform as expected. The condition was for the majority classified as a peripheral disorder, but over time it is possible that it has developed into a central type of disorder [11]. Patients may have problems with weighting and integration of input resulting in inadequate problem-solving capacity, and consequent motor output. The acquired dysfunctional body strategies may retard recovery and assist in cementation of a balance disorder. In our MVRT programme, *movement* was the active coping strategy that holds a potential to return the individual towards a more normalised life by rendering balance control an automatic and unconscious process.

## Conclusions and implications

The translated condition specific instrument, VSS-SF(NV), was found to be psychometrically sound. However, responsiveness needs to be further examined, as does cut-points with respect to severity in view of the acute-chronic condition.

Use of the VSS-SF(NV) revealed persistent, severe dizziness in a group of patients. Dizziness was particularly predicted by long symptom duration and neck pain. It is possible that the results are compatible with a sub-optimal compensation process. It is necessary to increase knowledge regarding treatment among health care professionals and to look into referral routines. Patients with long-lasting dizziness might benefit from, and should be offered, vestibular rehabilitation.

Improved balance control was seen following the MVRT intervention. Testing balance in challenging tasks such as gait might be important to detect change in functional status. Testing could be done in even more challenging situations than that of the present study. Use of next generation of accelerometers, which also register trunk rotations, may advance further knowledge with respect to the control of balance during gait. There is also a need to look into clinical tests of balance control as this is currently lacking.

Musculoskeletal function globally as well as within domains, indicated a more versatile and adaptable body. It could be important to also address musculoskeletal problems in patients with long-lasting dizziness as they may sustain and reinforce dizziness. A shorter version of the GPE-52 instrument, paying particular attention to the upper body and to respiration might be sufficient, but both sides should be examined for potential asymmetries. This needs to be explored in future studies.

The modified vestibular rehabilitation programme developed for the present work, was based on a body awareness approach incorporating the more traditional approaches of vestibular rehabilitation. The programme addresses musculoskeletal problems in addition to dizziness and balance. Compensation is promoted through movements which are introduced as active coping strategies and central for the learning process. The design of the intervention studies does not allow definite conclusions about effect of the intervention. This needs to be explored in larger samples under controlled conditions





---

## References

1. Baloh RW: Approach to the evaluation of the dizzy patient. *Otolaryngol Head Neck Surg* 1995, 112: 3-7.
2. Cooksey FS: Rehabilitation in vestibular injuries. *Proc R Soc Med* 1946, 39: 273-277.
3. Herdman SJ: *Vestibular rehabilitation*, 1st. edn. Philadelphia: F.A Davis; 1994.
4. Jayarajan V, Rajenderkumar D: A survey of dizziness management in General Practice. *Journal of Laryngology and Otology* 2003, 117: 599-604.
5. Holmberg J, Karlberg M, Harlacher U, Rivano-Fischer M, Magnusson M: Treatment of phobic postural vertigo : A controlled study of cognitive-behavioral therapy and self-controlled desensitization. *J Neurol* 2006, 253: 500-506.
6. Yardley L, Redfern MS: Psychological factors influencing recovery from balance disorders. *J Anxiety Disord* 2001, 15: 107-119.
7. Dix MR: The rationale and technique of head exercises in the treatment of vertigo. *Acta Otorhinolaryngol Belg* 1979, 33: 370-384.
8. Nazareth I, Yardley L, Owen N, Luxon L: Outcome of symptoms of dizziness in a general practice community sample. *Fam Pract* 1999, 16: 616-618.
9. Nazareth I, Landau S, Yardley L, Luxon L: Patterns of presentations of dizziness in primary care--a cross-sectional cluster analysis study. *J Psychosom Res* 2006, 60: 395-401.
10. Hansson EE, Månsson NO, Håkonsson AA: What happens with the dizzy patient in primary health care? Does education influence treatment? *Advances in Physiotherapy* 2004, 93-96.
11. Berthoz A, Viaud-Delmon I: Multisensory integration in spatial orientation. *Curr Opin Neurobiol* 1999, 9: 708-712.
12. Blakley BW, Goebel J: The meaning of the word "vertigo". *Otolaryngol Head Neck Surg* 2001, 125: 147-150.
13. Furman JM, Jacob RG: A clinical taxonomy of dizziness and anxiety in the otoneurological setting. *J Anxiety Disord* 2001, 15: 9-26.

14. Kroenke K, Lucas CA, Rosenberg ML, Scherokman B, Herbers JE, Jr., Wehrle PA *et al.*: Causes of persistent dizziness. A prospective study of 100 patients in ambulatory care. *Ann Intern Med* 1992, 117: 898-904.
15. Neuhauser HK, von Brevern M, Radtke A, Lezius F, Feldmann M, Ziese T *et al.*: Epidemiology of vestibular vertigo: a neurotologic survey of the general population. *Neurology* 2005, 65: 898-904.
16. Neuhauser HK: Epidemiology of vertigo. *Curr Opin Neurol* 2007, 20: 40-46.
17. Neuhauser HK, Radtke A, von BM, Lezius F, Feldmann M, Lempert T: Burden of dizziness and vertigo in the community. *Arch Intern Med* 2008, 168: 2118-2124.
18. Hannaford PC, Simpson JA, Bisset AF, Davis A, McKerrow W, Mills R: The prevalence of ear, nose and throat problems in the community: results from a national cross-sectional postal survey in Scotland. *Fam Pract* 2005, 22: 227-233.
19. Prieto L, Santed R, Cobo E, Alonso J: A new measure for assessing the health-related quality of life of patients with vertigo, dizziness or imbalance: the VDI questionnaire. *Qual Life Res* 1999, 8: 131-139.
20. Taber CW: *Taber's Cyclopedic Medical Dictionary*, 11th edn. Oxford: Blackwell Scientific Publications Ltd.; 1969.
21. Baloh RW: Clinical practice. Vestibular neuritis. *N Engl J Med* 2003, 348: 1027-1032.
22. Borel L, Harlay F, Lopez C, Magnan J, Chays A, Lacour M: Walking performance of vestibular-defective patients before and after unilateral vestibular neurotomy. *Behav Brain Res* 2004, 150: 191-200.
23. Yardley L, Beech S, Zander L, Evans T, Weinman J: A randomized controlled trial of exercise therapy for dizziness and vertigo in primary care. *Br J Gen Pract* 1998, 48: 1136-1140.
24. Pavlou M, Shumway-Cook A, Horak F, Yardley L, Bronstein A: Rehabilitation of balance disorders in the patients with vestibular pathology. In *Clinical disorders of balance, posture and gait*. Edited by Bronstein A, Brandt T, Woollacott M, Nutt J. London: Arnold; 2004:317-343.
25. World Health Organization. International Classification of Functioning, Disability and Health: ICF. 2001. Geneva, Switzerland. Ref Type: Report

- 
26. Kingma H: Function and dysfunction of the vestibular system. In *Textbook of audiological medicine*. Edited by Luxon L, Furman JM, Martini A, Stephens D. London: Martin Dunitz; 2003:665-670.
  27. Shumway-Cook A, Woollacott M: Normal postural control. In *Motor control. Translating theory into clinical practice*. Philadelphia: Lippincott Williams & Wilkins; 2007:157-186.
  28. Hain T, Helminski JO: Anatomy and physiology of the vestibular system. In *Vestibular rehabilitation*. Edited by Herdman SJ. Philadelphia: F.A. Davies Company; 2007:2-18.
  29. Curthoys IS, Halmagyi GM: Vestibular compensation: Clinical changes in vestibular function with time after unilateral loss. In *Vestibular rehabilitation*. Edited by Herdman SJ. Philadelphia: F. A Davies; 2007:76-97.
  30. Lacour M: Restoration of vestibular function: basic aspects and practical advances for rehabilitation. *Curr Med Res Opin* 2006, 22: 1651-1659.
  31. Palla A, Straumann D, Bronstein AM: Vestibular neuritis: vertigo and the high-acceleration vestibulo-ocular reflex. *J Neurol* 2008, 255: 1479-1482.
  32. Brandt T: Management of vestibular disorders. *J Neurol* 2000, 247: 491-499.
  33. Zee DS: Vestibular adaptation. In *Vestibular rehabilitation*. Edited by Herdman SJ. Philadelphia: F.A. Davies Company; 2007:19-31.
  34. Curthoys IS, Halmagyi GM: Vestibular compensation. *Adv Otorhinolaryngol* 1999, 55: 82-110.
  35. Igarashi M, Levy JK, Uchi T, Reschke MF: Further study of physical exercise and locomotor balance compensation after unilateral labyrinthectomy in squirrel monkeys. *Acta Otolaryngol* 1981, 92: 101-105.
  36. Beidel DC, Horak FB: Behavior therapy for vestibular rehabilitation. *J Anxiety Disord* 2001, 15: 121-130.
  37. Fetter M: Vestibular system disorders. In *Vestibular rehabilitation*. Edited by Herdman SJ. Philadelphia: F. A Davies; 2007:76-97.
  38. Brandt T, Steddin S, Daroff RB: Therapy for benign paroxysmal positioning vertigo, revisited. *Neurology* 1994, 44: 796-800.
  39. Hilton M, Pinder D: The Epley (canalith repositioning) manoeuvre for benign paroxysmal positional vertigo. *Cochrane Database Syst Rev* 2004, CD003162.

40. Gross EM, Ress BD, Viirre ES, Nelson JR, Harris JP: Intractable benign paroxysmal positional vertigo in patients with Meniere's disease. *Laryngoscope* 2000, 110: 655-659.
41. Brandt T, Huppert D, Hecht J, Karch C, Strupp M: Benign paroxysmal positioning vertigo: a long-term follow-up (6-17 years) of 125 patients. *Acta Otolaryngol* 2006, 126: 160-163.
42. Helminski JO, Janssen I, Hain TC: Daily exercise does not prevent recurrence of benign paroxysmal positional vertigo. *Otol Neurotol* 2008, 29: 976-981.
43. Yardley L, Dibb B, Osborne G: Factors associated with quality of life in Meniere's disease. *Clin Otolaryngol* 2003, 28: 436-441.
44. Mattox DE: Surgical management of vestibular disorders. In *Vestibular*. Edited by Herdman SJ. Philadelphia: F. A Davies; 2007:205-213.
45. Myrseth E, Moller P, Wentzel-Larsen T, Goplen F, Lund-Johansen M: Untreated vestibular schwannomas: vertigo is a powerful predictor for health-related quality of life. *Neurosurgery* 2006, 59: 67-76.
46. Enticott JC, O'leary SJ, Briggs RJ: Effects of vestibulo-ocular reflex exercises on vestibular compensation after vestibular schwannoma surgery. *Otol Neurotol* 2005, 26: 265-269.
47. Wrisley DM, Sparto PJ, Whitney SL, Furman JM: Cervicogenic dizziness: a review of diagnosis and treatment. *J Orthop Sports Phys Ther* 2000, 30: 755-766.
48. Malmström EM, Karlberg M, Melander A, Magnusson M, Moritz U: Cervicogenic dizziness - musculoskeletal findings before and after treatment and long-term outcome. *Disabil Rehabil* 2007, 29: 1193-1205.
49. Brandt T, Bronstein AM: Cervical vertigo. *J Neurol Neurosurg Psychiatry* 2001, 71: 8-12.
50. Guilemany JM, Martinez P, Prades E, Sanudo I, De Espana R, Cuchi A: Clinical and epidemiological study of vertigo at an outpatient clinic. *Acta Otolaryngol* 2004, 124: 49-52.
51. Arya AK, Nunez DA: What proportion of patients referred to an otolaryngology vertigo clinic have an otological cause for their symptoms? *J Laryngol Otol* 2008, 122: 145-149.
52. Ihlebaek C, Eriksen HR, Ursin H: Prevalence of subjective health complaints (SHC) in Norway. *Scand J Public Health* 2002, 30: 20-29.

- 
53. Stevens KN, Lang IA, Guralnik JM, Melzer D: Epidemiology of balance and dizziness in a national population: findings from the English Longitudinal Study of Ageing. *Age Ageing* 2008, 37: 300-305.
  54. Jönsson R, Sixt E, Landahl S, Rosenhall U: Prevalence of dizziness and vertigo in an urban elderly population. *J Vestib Res* 2004, 14: 47-52.
  55. Wiltink J, Tschan R, Michal M, Subic-Wrana C, Eckhardt-Henn A, Dieterich M *et al.*: Dizziness: anxiety, health care utilization and health behavior--results from a representative German community survey. *J Psychosom Res* 2009, 66: 417-424.
  56. van der Windt DA, Dunn KM, Spies-Dorgelo MN, Mallen CD, Blankenstein AH, Stalman WA: Impact of physical symptoms on perceived health in the community. *J Psychosom Res* 2008, 64: 265-274.
  57. Yardley L, Owen N, Nazareth I, Luxon L: Prevalence and presentation of dizziness in a general practice community sample of working age people. *Br J Gen Pract* 1998, 48: 1131-1135.
  58. Garrigues HP, Andres C, Arbaizar A, Cerdan C, Meneu V, Oltra JA *et al.*: Epidemiological aspects of vertigo in the general population of the Autonomic Region of Valencia, Spain. *Acta Otolaryngol* 2008, 128: 43-47.
  59. Bentsen BG, Hjortdal P: Hvorfor søker folk lege? *Tidsskr Nor Lægeforen* 1991, 2867-2870.
  60. Yardley L, Verschuur C, Masson E, Luxon L, Haacke N: Somatic and psychological factors contributing to handicap in people with vertigo. *Br J Audiol* 1992, 26: 283-290.
  61. Skøien AK, Wilhelmsen K, Gjesdal S: Occupational disability caused by dizziness and vertigo: a register-based prospective study. *Br J Gen Pract* 2008, 58: 619-623.
  62. Cawthorne T: The physiological basis for head exercises. *Journal of Chartered Society of Physiotherapy* 1945, 30: 106-107.
  63. Bamiou DE, Davies RA, McKee M, Luxon LM: Symptoms, disability and handicap in unilateral peripheral vestibular disorders. Effects of early presentation and initiation of balance exercises. *Scand Audiol* 2000, 29: 238-244.
  64. Herdman SJ, Whitney SL: Interventions for the patient with vestibular hypofunction. In *Vestibular rehabilitation*. Philadelphia: F.A. Davies Company; 2007:309-359.

- 
65. Pavlou M, Lingeswaran A, Davies RA, Gresty MA, Bronstein AM: Simulator based rehabilitation in refractory dizziness. *J Neurol* 2004, 251: 983-995.
  66. Shepard NT, Telian SA: Programmatic vestibular rehabilitation. *Otolaryngol Head Neck Surg* 1995, 112: 173-182.
  67. Yardley L, Donovan-Hall M, Smith HE, Walsh BM, Mullee M, Bronstein AM: Effectiveness of primary care-based vestibular rehabilitation for chronic dizziness. *Ann Intern Med* 2004, 141: 598-605.
  68. Hillier SL, Hollohan V: Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. *Cochrane Database Syst Rev* 2007, CD005397.
  69. Hansson EE: Vestibular rehabilitation - for whom and how? A systematic review. *Advances in Physiotherapy* 2007, 106-116.
  70. Krebs DE, Gill-Body KM, Parker SW, Ramirez JV, Wernick-Robinson M: Vestibular rehabilitation: useful but not universally so. *Otolaryngol Head Neck Surg* 2003, 128: 240-250.
  71. Szturm T, Ireland DJ, Lessing-Turner M: Comparison of different exercise programs in the rehabilitation of patients with chronic peripheral vestibular dysfunction. *J Vestib Res* 1994, 4: 461-479.
  72. Chang CP, Hain TC: A theory for treating dizziness due to optical flow (visual vertigo). *Cyberpsychol Behav* 2008, 11: 495-498.
  73. Perez N, Santandreu E, Benitez J, Rey-Martinez J: Improvement of postural control in patients with peripheral vestibulopathy. *Eur Arch Otorhinolaryngol* 2006, 263: 414-420.
  74. McGibbon CA, Krebs DE, Parker SW, Scarborough DM, Wayne PM, Wolf SL: Tai Chi and vestibular rehabilitation improve vestibulopathic gait via different neuromuscular mechanisms: preliminary report. *BMC Neurol* 2005, 5: 3.
  75. Jauregui-Renaud K, Villanueva Padron LA, Cruz Gomez NS: The effect of vestibular rehabilitation supplemented by training of the breathing rhythm or proprioception exercises, in patients with chronic peripheral vestibular disease. *J Vestib Res* 2007, 17: 63-72.
  76. Thornquist E, Bunkan B.H.: *What is psychomotor therapy?* Norwegian University Press; 1991.
  77. Kvåle A, Ljunggren AE: Body awareness therapies. In *Encyclopedia of pain*. Edited by Schmidt RF, Willis W.D. Springer Reference; 2007:167-169.

- 
78. Bandura A: *Social foundations of thought and action; A social cognitive theory*. Englewood Cliffs, New Jersey: Prentice-Hall Inc.; 1986.
  79. Lethem J, Slade PD, Troup JD, Bentley G: Outline of a Fear-Avoidance Model of exaggerated pain perception - I. *Behav Res Ther* 1983, 21: 401-408.
  80. Skøien AK, Wilhelmsen K: Fysisk aktivitet - noe mer enn trening? In *Fysioterapi på terskelen. 13 perspektiver på faget*. Edited by Stokkenes G, Sudman T, Sæbø G. Kristiansand S: Høyskoleforlaget; 2001:157-172.
  81. Domholdt E: *Rehabilitation research Principles and applications*, 3rd. edn. St. Louis: Elsevier Saunders; 2005.
  82. Panacek EA: Survey-based research: performing the survey. *Air Med J* 2008, 27: 64-66.
  83. Schwartz RJ, Panacek EA: Basics of research (Part 7): Archival data research. *Air Med J* 1996, 15: 119-124.
  84. Christophersen KA: *Databehandling og statistisk analyse med SPSS*. Oslo: Unipub; 2003.
  85. Yardley L, Masson E, Verschuur C, Haacke N, Luxon L: Symptoms, anxiety and handicap in dizzy patients: development of the vertigo symptom scale. *J Psychosom Res* 1992, 36: 731-741.
  86. Yardley L, Luxon L, Lear S, Britton J: Vestibular and posturographic test results in people with symptoms of panic and agoraphobia. *Journal of audiological medicine* 1994, 48-65.
  87. Yardley L, Britton J, Lear S, Bird J, Luxon LM: Relationship between balance system function and agoraphobic avoidance. *Behav Res Ther* 1995, 33: 435-439.
  88. Yardley L, Gresty M, Bronstein A, Beyts J: Changes in heart rate and respiration rate in patients with vestibular dysfunction following head movements which provoke dizziness. *Biol Psychol* 1998, 49: 95-108.
  89. Yardley L, Medina SM, Jurado CS, Morales TP, Martinez RA, Villegas HE: Relationship between physical and psychosocial dysfunction in Mexican patients with vertigo: a cross-cultural validation of the vertigo symptom scale. *J Psychosom Res* 1999, 46: 63-74.
  90. Tschan R, Wiltink J, Best C, Bense S, Dieterich M, Beutel ME *et al.*: Validation of the German version of the Vertigo Symptom Scale (VSS) in patients with organic or somatoform dizziness and healthy controls. *J Neurol* 2008.

91. Mendel B, Bergenius J, Langius A: Dizziness symptom severity and impact on daily living as perceived by patients suffering from peripheral vestibular disorder. *Clin Otolaryngol* 1999, 24: 286-293.
92. Godemann F, Linden M, Neu P, Heipp E, Dorr P: A prospective study on the course of anxiety after vestibular neuronitis. *J Psychosom Res* 2004, 56: 351-354.
93. Cohen HS, Kimball KT, Stewart MG: Benign paroxysmal positional vertigo and comorbid conditions. *ORL J Otorhinolaryngol Relat Spec* 2004, 66: 11-15.
94. Pavlou M, Davies RA, Bronstein AM: The assessment of increased sensitivity to visual stimuli in patients with chronic dizziness. *J Vestib Res* 2006, 16: 223-231.
95. Yardley L, Kirby S: Evaluation of booklet-based self-management of symptoms in Meniere disease: a randomized controlled trial. *Psychosom Med* 2006, 68: 762-769.
96. Holmberg J, Karlberg M, Harlacher U, Magnusson M: One-year follow-up of cognitive behavioral therapy for phobic postural vertigo. *J Neurol* 2007, 254: 1189-1192.
97. Yardley L, Burgneay J, Andersson G, Owen N, Nazareth I, Luxon L: Feasibility and effectiveness of providing vestibular rehabilitation for dizzy patients in the community. *Clin Otolaryngol* 1998, 23: 442-448.
98. Yardley L, Jahanshahi M, Hallam RS: Psychosocial aspects of disorders affecting balance and gait. In *Clinical disorders of balance posture and gait*. Edited by Bronstein A, Brandt T, Woollacott M, Nutt J. London: Arnold; 2004:360-384.
99. Yanik B, Kulcu DG, Kurtais Y, Boynukalin S, Kurtarah H, Gokmen D: The reliability and validity of the Vertigo Symptom Scale and the Vertigo Dizziness Imbalance Questionnaires in a Turkish patient population with benign paroxysmal positional vertigo. *J Vestib Res* 2008, 18: 159-170.
100. Söderman AC, Bagger-Sjöback D, Bergenius J, Langius A: Factors influencing quality of life in patients with Meniere's disease, identified by a multidimensional approach. *Otol Neurotol* 2002, 23: 941-948.
101. Yardley L, Owen N, Nazareth I, Luxon L: Panic disorder with agoraphobia associated with dizziness: characteristic symptoms and psychosocial sequelae. *J Nerv Ment Dis* 2001, 189: 321-327.



- 
102. Kulcu DG, Yanik B, Boynukalin S, Kurtais Y: Efficacy of a home-based exercise program on benign paroxysmal positional vertigo compared with betahistine. *J Otolaryngol Head Neck Surg* 2008, 37: 373-379.
  103. Söderman AC, Bergenius J, Bagger-Sjöback D, Tjell C, Langius A: Patients' subjective evaluations of quality of life related to disease-specific symptoms, sense of coherence, and treatment in Meniere's disease. *Otol Neurotol* 2001, 22: 526-533.
  104. Green JD, Jr., Verrall A, Gates GA: Quality of life instruments in Meniere's disease. *Laryngoscope* 2007, 117: 1622-1628.
  105. Sartorius N, Kuyken W: Translation of health status instruments. In *Quality of life assessment: International perspectives*. Edited by Orly J, Kuyken W. Berlin: Springer-Verlag; 1994:3-18.
  106. Guillemin F, Bombardier C, Beaton D: Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. *J Clin Epidemiol* 1993, 46: 1417-1432.
  107. Streiner DL, Norman GR: *Health measurement scales: a practical guide to their development and use*, 3rd. edn. Oxford: Oxford University Press; 2003.
  108. Beaton DE, Bombardier C, Guillemin F, Ferraz MB: Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine* 2000, 25: 3186-3191.
  109. Prince F, Winter DA, Stergiou P, Walt SE: Anticipatory control of upper body balance during human locomotion. *Gait & Posture* 1994, 2: 19-25.
  110. Mulavara AP, Bloomberg JJ: Identifying head-trunk and lower limb contributions to gaze stabilization during locomotion. *J Vestib Res* 2002, 12: 255-269.
  111. Kavanagh JJ, Menz HB: Accelerometry: a technique for quantifying movement patterns during walking. *Gait Posture* 2008, 28: 1-15.
  112. Moe-Nilssen R: *Trunk accelerometry. A new method for assessing balance under various task and environmental constraints*. Doctoral thesis. University of Bergen; 1999.
  113. Moe-Nilssen R: A new method for evaluating motor control in gait under real-life environmental conditions. Part 2: Gait analysis. *Clin Biomech (Bristol, Avon)* 1998, 13: 328-335.
  114. Meichtry A, Romkes J, Gobelet C, Brunner R, Muller R: Criterion validity of 3D trunk accelerations to assess external work and power in able-bodied gait. *Gait Posture* 2007, 25: 25-32.

115. Moe-Nilssen R: Test-retest reliability of trunk accelerometry during standing and walking. *Arch Phys Med Rehabil* 1998, 79: 1377-1385.
116. Kavanagh JJ, Barrett R, Morrison S: The role of the neck and trunk in facilitating head stability during walking. *Exp Brain Res* 2006, 172: 454-463.
117. Moe-Nilssen R: A new method for evaluating motor control in gait under real-life environmental conditions. Part 1: The instrument. *Clin Biomech (Bristol, Avon)* 1998, 13: 320-327.
118. Moe-Nilssen R, Helbostad JL: Estimation of gait cycle characteristics by trunk accelerometry. *J Biomech* 2004, 37: 121-126.
119. Moe-Nilssen R, Helbostad JL: Interstride trunk acceleration variability but not step width variability can differentiate between fit and frail older adults. *Gait Posture* 2005, 21: 164-170.
120. Kavanagh JJ, Morrison S, James DA, Barrett R: Reliability of segmental accelerations measured using a new wireless gait analysis system. *J Biomech* 2006, 39: 2863-2872.
121. Zijlstra W: Assessment of spatio-temporal parameters during unconstrained walking. *Eur J Appl Physiol* 2004, 92: 39-44.
122. Lemoine R, Coroian C, Mastroianni T, Grundfest W: Accelerometers for quantification of gait and movement disorders: a perspective review. *Journal of Mechanics in Medicine & Biology* 2008, 8: 137-152.
123. Kavanagh JJ, Barrett RS, Morrison S: Upper body accelerations during walking in healthy young and elderly men. *Gait Posture* 2004, 20: 291-298.
124. Menz HB, Lord SR, Fitzpatrick RC: Age-related differences in walking stability. *Age Ageing* 2003, 32: 137-142.
125. Menz HB, Lord SR, Fitzpatrick RC: Acceleration patterns of the head and pelvis when walking on level and irregular surfaces. *Gait Posture* 2003, 18: 35-46.
126. Moe-Nilssen R, Helbostad JL, Akra T, Birdedal L, Nygaard HA: Modulation of gait during visual adaptation to dark. *J Mot Behav* 2006, 38: 118-125.
127. O'Sullivan M, Blake C, Cunningham C, Boyle G, Finucane C: Correlation of accelerometry with clinical balance tests in older fallers and non-fallers. *Age Ageing* 2009, 38: 308-313.
128. Helbostad JL, Leirfall S, Moe-Nilssen R, Sletvold O: Physical fatigue affects gait characteristics in older persons. *J Gerontol A Biol Sci Med Sci* 2007, 62: 1010-1015.

- 
129. Moe-Nilssen R, Ljunggren AE, Torebjork E: Dynamic adjustments of walking behavior dependent on noxious input in experimental low back pain. *Pain* 1999, 83: 477-485.
  130. Sundsvold MS, Vaglum P: Muscular pains and psychopathology: evaluation by the GPM method. In *Pain*. Edited by Michel TH. Oxford: Churchill Livingstone; 1985:18-47.
  131. Kvåle A: *Measurement properties of a global physiotherapy examination in patients with long-lasting musculoskeletal pain*. Doctoral thesis. University of Bergen; 2003.
  132. Kvåle A, Ljunggren AE, Johnsen TB: Examination of movement in patients with long-lasting musculoskeletal pain: reliability and validity. *Physiother Res Int* 2003, 8: 36-52.
  133. Kvåle A, Skouen JS, Ljunggren AE: Discriminative validity of the Global Physiotherapy Examination-52 in patients with long-lasting musculoskeletal pain versus healthy persons. *Journal of Musculoskeletal Pain* 2003, 11: 23-36.
  134. Kvåle A, Ellertsen B, Skouen J: Relationships between physical findings (GPE-78) and psychological profiles (MMPI-2) in patients with long-lasting musculoskeletal pain. *Nord J Psychiatry* 2001, 55: 177-184.
  135. Kvåle A, Skouen JS, Ljunggren AE: Sensitivity to change and responsiveness of the global physiotherapy examination (GPE-52) in patients with long-lasting musculoskeletal pain. *Phys Ther* 2005, 85: 712-726.
  136. Norman GR, Streiner DL: *Biostatistics: the bare essentials*, 2nd edn. Hamilton; Decker; 2000.
  137. Moe-Nilssen R, Nordin E, Lundin-Olsson L: Criteria for evaluation of measurement properties of clinical balance measures for use in fall prevention studies. *Journal of Evaluation in Clinical Practice* 2007, 1-5.
  138. Cohen ME: Analysis of ordinal dental data: evaluation of conflicting recommendations. *J Dent Res* 2001, 80: 309-313.
  139. Altman DG: *Practical statistics for medical research*, First edn. Chapman & Hall; 1991.
  140. Laurikkala J, Kentala E, Juhola M, Pyykkö I, Lammi S: Usefulness of imputation for the analysis of incomplete otoneurologic data. *Int J Med Inform* 2000, 58-59: 235-242.
  141. Hanley K, O'Dowd T, Considine N: A systematic review of vertigo in primary care. *Br J Gen Pract* 2001, 51: 666-671.

- 
142. Kroenke K, Hoffman RM, Einstadter D: How common are various causes of dizziness? A critical review. *South Med J* 2000, 93: 160-167.
  143. Bath AP, Walsh RM, Ranalli P, Tyndel F, Bance ML, Mai R *et al.*: Experience from a multidisciplinary "dizzy" clinic. *Am J Otol* 2000, 21: 92-97.
  144. Kroenke K: Studying symptoms: sampling and measurement issues. *Ann Intern Med* 2001, 134: 844-853.
  145. Ilstad S: *Survey-Metoden. En veiledning i utvalgsundersøkelser*. Tapir Forlag; 1989.
  146. Panacek EA, Thompson CB: Sampling methods: selecting your subjects. *Air Med J* 2007, 26: 75-78.
  147. Terwee CB, Bot SD, de Boer MR, van der Windt DA, Knol DL, Dekker J *et al.*: Quality criteria were proposed for measurement properties of health status questionnaires. *J Clin Epidemiol* 2007, 60: 34-42.
  148. Preacher KJ, MacCallum RC: Repairing Tom Swift's electric factor analysis machine. *Understanding Statistics* 2003, 2: 13-43.
  149. Fabrigar LR, Wegener DT, MacCallum RC, Strahan EJ: Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods* 1999, 4: 272-299.
  150. Finch E, Brooks D., Stratford PW, Mayo NE: *Physical rehabilitation outcome measures: A guide to enhanced clinical decision-making*, 2nd. edn. Baltimore: Lippincott Williams & Wilkins; 2002.
  151. Henriksen M, Lund H, Moe-Nilssen R, Bliddal H, Danneskiold-Samsoe B: Test-retest reliability of trunk accelerometric gait analysis. *Gait Posture* 2004, 19: 288-297.
  152. Rothstein JM, Echternach JL: *Primer on measurement: An introductory guide to measurement issues*. Alexandria: The American Physical Therapy Association; 1993.
  153. Simmonds M, Harding V, Watson P, Claveau Y: *Physical therapy assessment: expanding the model*. Seattle: IASP Press; 2000:1013-1030.
  154. Wilson IB, Cleary PD: Linking clinical variables with health-related quality of life. A conceptual model of patient outcomes. *JAMA* 1995, 273: 59-65.
  155. Kroenke K: Dizziness in primary care. *West J Med* 1995, 162: 73-74.
  156. Jacobson GP, Newman CW: The development of the Dizziness Handicap Inventory. *Arch Otolaryngol Head Neck Surg* 1990, 116: 424-427.

- 
157. Honrubia V, Bell TS, Harris MR, Baloh RW, Fisher LM: Quantitative evaluation of dizziness characteristics and impact on quality of life. *Am J Otol* 1996, 17: 595-602.
  158. Ware JE, Kosinski M, Gandek B: *SF-36 Health survey, manual and interpretation guide*, 2nd. edn. Boston: The New England Medical Center; 2000.
  159. Meli A, Zimatore G, Badaracco C, De AE, Tufarelli D: Vestibular rehabilitation and 6-month follow-up using objective and subjective measures. *Acta Otolaryngol* 2006, 126: 259-266.
  160. Badke MB, Miedaner JA, Shea TA, Grove CR, Pyle GM: Effects of vestibular and balance rehabilitation on sensory organization and dizziness handicap. *Ann Otol Rhinol Laryngol* 2005, 114: 48-54.
  161. Cunha F, Settanni FA, Gananca FF: What is the effect of dizziness on the quality of life for patients with Meniere's disease? *Rev Laryngol Otol Rhinol (Bord)* 2005, 126: 155-158.
  162. Tufarelli D, Meli A, Alesii A, De AE, Badaracco C, Falcioni M *et al.*: Quality of life after acoustic neuroma surgery. *Otol Neurotol* 2006, 27: 403-409.
  163. Monzani D, Casolari L, Guidetti G, Rigatelli M: Psychological distress and disability in patients with vertigo. *J Psychosom Res* 2001, 50: 319-323.
  164. Perez N, Martin E, Garcia-Tapia R: Dizziness: relating the severity of vertigo to the degree of handicap by measuring vestibular impairment. *Otolaryngol Head Neck Surg* 2003, 128: 372-381.
  165. Coelho DH, Roland JT, Jr., Rush SA, Narayana A, St CE, Chung W *et al.*: Small vestibular schwannomas with no hearing: comparison of functional outcomes in stereotactic radiosurgery and microsurgery. *Laryngoscope* 2008, 118: 1909-1916.
  166. Lopez-Escamez JA, Gamiz MJ, Fernandez-Perez A, Gomez-Finana M: Long-term outcome and health-related quality of life in benign paroxysmal positional vertigo. *Eur Arch Otorhinolaryngol* 2005, 262: 507-511.
  167. Duracinsky M, Mosnier I, Bouccara D, Sterkers O, Chassany O: Literature review of questionnaires assessing vertigo and dizziness, and their impact on patients' quality of life. *Value Health* 2007, 10: 273-284.
  168. Morris AE, Lutman ME, Yardley L: Measuring outcome from Vestibular Rehabilitation, Part I: Qualitative development of a new self-report measure. *Int J Audiol* 2008, 47: 169-177.

- 
169. Clendaniel RA: Outcome measures for assessment of treatment of the dizzy and balance disorder patient. *Otolaryngol Clin North Am* 2000, 33: 519-533.
  170. Kroenke K, Lucas C, Rosenberg ML, Scherokman B, Herbers JE: One-year outcome for patients with a chief complaint of dizziness. *J Gen Intern Med* 1994, 9: 684-689.
  171. Allum JH, Adkin AL: Improvements in trunk sway observed for stance and gait tasks during recovery from an acute unilateral peripheral vestibular deficit. *Audiol Neurootol* 2003, 8: 286-302.
  172. Crane BT, Demer JL: Effects of vestibular and cerebellar deficits on gaze and torso stability during ambulation. *Otolaryngol Head Neck Surg* 2000, 123: 22-29.
  173. Mamoto Y, Yamamoto K, Imai T, Tamura M, Kubo T: Three-dimensional analysis of human locomotion in normal subjects and patients with vestibular deficiency. *Acta Otolaryngol* 2002, 122: 495-500.
  174. Taguchi K, Hirabayashi C, Kikukawa M: Clinical significance of head movement while stepping. *Acta Otolaryngol Suppl* 1984, 406: 125-128.
  175. Ratcliffe RJ, Holt KG: Low frequency shock absorption in human walking. *Gait & Posture* 1997, 5: 93-100.
  176. Kavanagh JJ, Morrison S, Barrett RS: Coordination of head and trunk accelerations during walking. *Eur J Appl Physiol* 2005, 94: 468-475.
  177. Krebs DE, Goldvasser D, Lockert JD, Portney LG, Gill-Body KM: Is base of support greater in unsteady gait? *Phys Ther* 2002, 82: 138-147.
  178. Allum JH, Adkin AL, Carpenter MG, Held-Ziolkowska M, Honegger F, Pierchala K: Trunk sway measures of postural stability during clinical balance tests: effects of a unilateral vestibular deficit. *Gait Posture* 2001, 14: 227-237.
  179. Bronstein A: Posturography. In *Textbook of audiological medicine*. Edited by Luxon L, Furman JM, Martini A, Stephens D. London: Martin Dunitz; 2003:747-758.
  180. Evans MK, Krebs DE: Posturography does not test vestibulospinal function. *Otolaryngol Head Neck Surg* 1999, 120: 164-173.
  181. O'Neill DE, Gill-Body KM, Krebs DE: Posturography changes do not predict functional performance changes. *Am J Otol* 1998, 19: 797-803.
  182. Wrisley DM, Marchetti GF, Kuharsky DK, Whitney SL: Reliability, internal consistency, and validity of data obtained with the functional gait assessment. *Phys Ther* 2004, 84: 906-918.

- 
183. Shumway-Cook A, Baldwin M, Polissar NL, Gruber W: Predicting the probability for falls in community-dwelling older adults. *Phys Ther* 1997, 77: 812-819.
  184. Wilhelmsen K, Tamber AL. The Dynamic Gait Index. [www.legeforeningen.no/id/18662.0](http://www.legeforeningen.no/id/18662.0). 2008. Ref Type: Electronic Citation
  185. Horak FB, Wrisley DM, Frank J: The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Phys Ther* 2009, 89: 484-498.
  186. Faag C, Bergenius J, Forsberg C, Langius-Eklof A: Symptoms experienced by patients with peripheral vestibular disorders: evaluation of the Vertigo Symptom Scale for clinical application. *Clin Otolaryngol* 2007, 32: 440-446.
  187. Whitney SL, Herdman SJ: Physical therapy assessment of vestibular hypofunction. In *Vestibular rehabilitation*. Edited by Herdman SJ. Philadelphia: F.A. Davies; 2007:333-372.
  188. Smith-Wheelock M, Shepard NT, Telian SA: Physical therapy program for vestibular rehabilitation. *Am J Otol* 1991, 12: 218-225.
  189. Cieza A, Geyh S, Chatterji S, Kostanjsek N, Ustun B, Stucki G: Icf linking rules: An update based on lessons learned. *Journal of Rehabilitation Medicine* 2005, 37: 212-218.
  190. Berg K, Finne-Soveri H, Gray L, Henrard JC, Hirdes J, Ikegami N *et al.*: Relationship between interRAI HC and the ICF: opportunity for operationalizing the ICF. *Bmc Health Services Research* 2009, 9.
  191. Cieza A, Hilfiker R, Chatterji S, Kostanjsek N, Ustun BT, Stucki G: The International Classification of Functioning, Disability, and Health could be used to measure functioning. *Journal of Clinical Epidemiology* 2009, 62: 899-911.
  192. Mulavara AP, Houser J, Miller C, Bloomberg JJ: Full-body gaze control mechanisms elicited during locomotion: effects of VOR adaptation. *J Vestib Res* 2005, 15: 279-289.
  193. Vlaeyen JW, Linton SJ: Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *Pain* 2000, 85: 317-332.
  194. Bird JC, Beynon GJ, Prevost AT, Baguley DM: An analysis of referral patterns for dizziness in the primary care setting. *Br J Gen Pract* 1998, 48: 1828-1832.
  195. Nazareth I, Yardley L: A clinical approach to dizziness. *JCOM* 2002, 9: 159-167.

196. McGibbon CA, Krebs DE, Wolf SL, Wayne PM, Scarborough DM, Parker SW: Tai Chi and vestibular rehabilitation effects on gaze and whole-body stability. *J Vestib Res* 2004, 14: 467-478.
197. Sakellari V, Bronstein AM, Corna S, Hammon CA, Jones S, Wolsley CJ: The effects of hyperventilation on postural control mechanisms. *Brain* 1997, 120 (Pt 9): 1659-1673.
198. Keim RJ, Cook M, Martini D: Balance rehabilitation therapy. *Laryngoscope* 1992, 102: 1302-1307.