Dizziness, balance and rehabilitation in vestibular disorders
To my husband Owe
and our children Johan and Erik
LENA KOLLÉN

Dizziness, balance and rehabilitation in vestibular disorders
Abstract


Dizziness and balance problems are common symptoms at all ages. The aims were; to evaluate rehabilitation, static, dynamic balance and recovery in acute unilateral vestibular loss (AUWL), to evaluate the treatment of benign paroxysmal positional vertigo (BPPV) with assessment of static and dynamic balance and to evaluate the prevalence of dizziness and BPPV in a population of 75-year-olds.

Study 1: Twenty-seven patients (51years) with AUWL were included and the recovery was followed regarding vestibular function, dizziness, and sick-leave. The recovery was rapid, with disappearance of spontaneous nystagmus and rapid return to work.

Study II: Forty two patents (51 years) with AUWL were included and compared with a reference group. Static and dynamic balance were assessed after six months. Significant instability was found both in static and dynamic balance compared to a reference group.

Study III. Seventeen patients (52 years) with severe BPPV (> 3 months) were treated with Semont’s manoeuvre and/or Brandt-Daroff exercises. The recovery was evaluated by Dix-Hallpike test, subjective dizziness, unsteadiness and balance tests, after 1, 6 and 12 months. Semont’s manoeuvre resolved dizziness but the long term follow up showed impaired balance.

Study IV: A large cohort (675) of elderly was assessed regarding dizziness and BPPV. Side lying test and balance tests were applied. A high prevalence of dizziness (36%) and BPPV (11%) was found.

Conclusions: Patients with AUWL and BPPV have despite good symptomatic relief, still impaired static and dynamic balance at long term follow up. BPPV in elderly is common and should be examined since it can be treated.

Keywords: benign paroxysmal positional vertigo, static balance, dynamic balance, unilateral vestibular loss, dizziness, walking, vestibular rehabilitation.

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List of publications

This thesis is based on the studies reported in the following papers, which are referred to in the text by their respective Roman numerals.

I. Recovery after early vestibular rehabilitation in patients with acute unilateral vestibular loss.
   Bjerlemo B, Kollén L, Borderos I, Kreuter M, Möller C.

II. Static and dynamic balance and well-being after acute unilateral vestibular loss.
   Kollén L, Bjerlemo B, Fagevik-Olsén M, Möller C.

III. Evaluation of treatment in benign paroxysmal positional vertigo (BPPV).
    Kollén L, Bjerlemo B, Möller C.
    Advances in Physiotherapy 2006;8:3,106-115.

IV. Benign Paroxysmal Positional Vertigo is a common cause of dizziness and unsteadiness in a large population of 75-year-olds.
    Kollén L, Frändin K, Möller M, Fagevik Olsén M, Möller C.
    Submitted to: Aging Clinical and Experimental Research
### Abbreviations

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<tr>
<th>Abbreviation</th>
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<tr>
<td>AUVL</td>
<td>Acute unilateral vestibular loss</td>
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<td>BPPV</td>
<td>Benign paroxysmal positional vertigo</td>
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<tr>
<td>CNS</td>
<td>Central nervous system</td>
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<td>ENG</td>
<td>Electronystagmography</td>
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<tr>
<td>ENT</td>
<td>Ear, nose and throat</td>
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<td>EOG</td>
<td>Electro-oculography</td>
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<td>HSN</td>
<td>Head shake nystagmus</td>
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<tr>
<td>MLF</td>
<td>Medial longitudinal fasciculus</td>
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<tr>
<td>ICC</td>
<td>Intra class correlation</td>
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<tr>
<td>SREO</td>
<td>Sharpened Romberg with eyes open</td>
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<tr>
<td>SREC</td>
<td>Sharpened Romberg with eyes closed</td>
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<tr>
<td>SOLEO</td>
<td>Standing on one leg with the eyes open</td>
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<tr>
<td>SOLEC</td>
<td>Standing on one leg with the eyes closed</td>
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<td>VAS</td>
<td>Visual analogue scale</td>
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<td>VEMP</td>
<td>Vestibular evoked myogenic potential</td>
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<td>VN</td>
<td>Videonystagmoscopy</td>
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<td>VOR</td>
<td>Vestibulo-ocular reflex</td>
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<td>OKN</td>
<td>Optokinetic nystagmus</td>
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### Definitions

**Adaptation**

The adjustment of sensory systems to environment, enabling function adequately in a new or changed environment.

**Alexander’s law**

The degrees of nystagmus, the first degree only with gaze in the direction of the fast component, second degree in mid position and in the direction of the fast component, third degree present in all directions.

**Central vestibular compensation**

To reduce responsiveness to stimuli and to re-balance activity within the vestibular nuclei.

**Dizziness**

A sensation of a disturbed relationship with surrounding objects in space, without a feeling of vertigo.

**Habituation**

A central process that is independent of sensory adaptation and motor fatigue. The repeated stimulation leads to the rearrangement of the pattern, so that habituation to the initially challenging stimulation takes place within a few days. Sensitization is an increased response to the stimuli.

**Nystagmus**

An oscillation of the eye which is initiated by a slow eye movement accompanied by a fast (saccadic) eye movement.

**Optokinetic nystagmus (OKN)**

To stabilize an entire visual field by maintaining the position of a single target on the fovea.
Definitions

Adaptation
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Optokinetic nystagmus (OKN)
To stabilize an entire visual field by maintaining the position of a single target on the fovea\textsuperscript{46}.
Postural Control
Controlling the body’s position in space for stability. It is defined as an ability to maintain an appropriate relationship between the body segments and between the body and the environment\textsuperscript{140}.

Substitution
Other mechanisms such as vision and sensory may compensate\textsuperscript{18}.

Vertigo
Vertigo is an illusion of movement\textsuperscript{79}.

Unsteadiness
A feeling of being unstable when sitting, standing and walking\textsuperscript{11}.

Saccadic system
Rapid eye movements to shift gaze accurately between different points, which can be executed either voluntarily or involuntarily\textsuperscript{46}.

Smooth pursuit
Tracking eye movement and stabilizing a moving target on the fovea by producing eye velocities closely matching the target velocities\textsuperscript{85}.

The Jongkees formula\textsuperscript{71}
\[
\frac{(R^{30^\circ} + R^{44^\circ}) - (L^{30^\circ} + L^{44^\circ})}{R^{30^\circ} + R^{44^\circ} + L^{30^\circ} + L^{44^\circ}} \times 100 = \% 
\]
Introduction

As a physiotherapist working in the neurology department twenty years ago I often met patients suffering from dizziness or vertigo. At that time, it was hard to find information of how to examine and treat these patients. This is the background to my interest in this field. The studies in this thesis were initiated by my supervisor Claes Möller in 1999 when I was recruited to investigate the natural course of acute unilateral vestibular loss (AUVL). The original studies were financed by grants from the Västra Götaland Region.

The knowledge concerning recovery of AUVL was in 1999 not fully understood. The original plans were to compare the recovery in patients who have had a “classical treatment” with bed rest to patients who have undergone vestibular rehabilitation. Due to the growing knowledge of the importance of active rehabilitation, we decided for ethical reasons to undertake a study without a control group.

Studies of the general population in different countries reveal that the prevalence of dizziness is approximately 20-30%. The causes of dizziness can be manifold and include disturbances of the peripheral vestibular function and central nervous system disorders. The prevalence of dizziness in elderly persons aged 70-75 in Sweden has been reported to be 36% for women and 29% for men. Every year, approximately 30% of elderly people fall, often with fractures as a result. Ekwall et al. 2009 found that dizziness was associated with falls in 31% of subjects with dizziness compared to 15% among those without dizziness. Asymmetric vestibular function is overrepresented in elderly persons with hip fractures and wrist fractures. In elderly persons, the history may be less obvious compared with younger patients, since elderly persons with vestibular problems may not complain of vertigo but may present with other problems such as falling. Dizziness is often accompanied by secondary psychological problems such as anxiety, or phobic avoidance of situations and movements associated with dizziness. In the majority of elderly with dizziness, an etiology is not evident.

Postural control

Postural control and balance are essential for standing, turning around, walking, running and obtaining environmental information. Maintaining balance is a complex act in which continuous information from somatosensory, visual and vestibular sources is processed by the CNS. Any failure or dysfunction may result in vertigo, dizziness, impaired balance and unsteadiness. During quiet stance, healthy subjects control their
upright posture with small movements made in different segments of the body. The task of postural control involves controlling the position in space for stability, defined as controlling the centre of body mass within the base of support and orientation. Postural orientation could be defined as an ability to maintain an appropriate relationship between the body segments, the body and the environment\(^\text{140}\). The word “stability” is synonymous with equilibrium. A body is in equilibrium either when it is at rest (static equilibrium) or when it is in steady motion (dynamic equilibrium)\(^\text{140}\). A balanced stance requires the ability to move one’s position while standing and to move out of the standing position. This includes the ability to shift weight in the lateral and anterior-posterior directions and to make flexible movements in the vertical direction\(^\text{140}\). The postural control system has two main functions: first, to build up postural stability to maintain balance and second, the orientation and position of the segments that serve as a reference frame for perception and action with respect to the external world. This dual function of postural control is based on three components; the impulses from the vestibular system of the inner ear, the eyes and somatosensory stimuli from the skin, muscles, tendons and joints. Dysfunction in this complex system can lead to vertigo, dizziness or imbalance\(^\text{22, 111, 140}\) (Fig. 1).

**Figure 1.** Schematic illustration of human postural control (permission by Magnusson M.)

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The vestibular system

The most important role when it comes to vestibular information for postural control is to control the orientation of the head and trunk in space in terms of gravity inertial forces\textsuperscript{61}. The vestibular labyrinth is located in the temporal bone lateral and posterior to the cochlea. Surrounding the membranous labyrinth there is perilymph, and inside the membranous labyrinth is the endolymph\textsuperscript{53}. In contrast to the perilymph, the endolymph has a high concentration of potassium, thereby creating a suitable environment for the vestibular hair cells. The vestibular system consists of three semicircular canals (SCC) and two otolithic organs. The three semicircular canals (lateral, posterior and anterior) respond to angular acceleration and are orthogonal to one another. The otolith system registers information about linear acceleration and deceleration (Fig.2). The labyrinth is innervated by nervus vestibularis (N. VIII)\textsuperscript{130}.

Figure 2. Illustration of the peripheral vestibular organ with the three semicircular canals, otolithic organs (utriculus and sacculus) reprinted from CMAJ, 30 September 2003; 169(7), page(s) 681-693, with the permission of the publisher. © 2003 Canadian Medical Association
The endolymph moves freely within each canal in response to the direction of the angular head rotation. In the distended part of each canal (ampullae), the sensory hair cells (kinocilia/stereocilia) are formed to create a structure called the cupula. The hairs from the sensory cells are of two kinds, type I and II. The sensory hair cells are orientated in the horizontal canal so that endolymph motion towards the ampulla causes excitation. In the sensory hair cells of the vertical semicircular canals (posterior and anterior), a depolarization occurs when the endolymph moves away from the ampulla\textsuperscript{129,130}(Fig. 3).

**Figure 3.** Cross-section of the crista ampullaris in the posterior canal showing the kinocilia and stereocilia of hair cells projecting into the cupula. Reprinted from CMAJ, 30 September 2003;169(7),page(s)681-693, with the permission of the publisher. © 2003 Canadian Medical Association.
Sensory hair cells in the otolthic organs (sacculus and utriculus) project into a gelatinous material with calcium carbonate crystals (otoconia), which provides the otolthic organs with an inertial mass (the maculae). The maculae of the utriculus and sacculus respond to linear acceleration and deceleration, including the force of gravity, as the head is placed in different positions. Both the utriculus and sacculus have a central region known as the striola, which divides the otolthic organs into two parts. The sensory hair cells (kinocilia) of the utriculus are oriented toward the striola, whereas the sensory hair cells (kinocilia) of the sacculus are oriented away from the striola\textsuperscript{129, 130}. The sliding movements of the otolthic mass bend the sensory hairs and stimulate the sensory nerve endings. Impulses are then transmitted to execute compensatory eye movements (macular-ocular reflex) and to promote stable body posture (macular-spinal reflex)\textsuperscript{56}. The vestibular nerve forms two major divisions called the superior and inferior branches. The superior vestibular nerve innervates the horizontal and anterior semicircular canals and the utriculus. The inferior vestibular nerve innervates the posterior semicircular canal and the sacculus\textsuperscript{129, 130}.

Angular head movements in the horizontal semicircular canals cause endolymph movements which deviates the cupula. The cupula of the horizontal canal will move in the opposite direction to the rotation during acceleration. Head movements to the right will create a utricular (ampullo)-petal endolymph movement in the right canal and a utricular-fugal movement in the left canal. The constant resting discharge will be increased or decreased depending on the direction of the flow. The eye movement responses from utricular-petal stimulation are larger compared with utricular-fugal stimulation. This is known as Ewald’s law\textsuperscript{4, 51}. In its most basic form, the pathways controlling Vestibulo-Ocular Reflex (VOR) can be described as a three-neuron arc (Fig. 4)\textsuperscript{22, 130}. 
Visual inputs report information on the position and motion of the head in relation to surrounding objects. Visual information is important for the orientation of self-motion in different environments\textsuperscript{140}. The saccades are rapid eye movements that causes the eyes to shift gaze accurately between different points and this can be executed voluntarily or involuntarily\textsuperscript{46}. Smooth pursuit refers to tracking eye movements in order to stabilize a moving target on the fovea by producing eye velocities closely matching the target velocities\textsuperscript{85}. In daily life activities, humans perform visual tracking by a combination of smooth pursuit, saccades and vergence eye movements\textsuperscript{109}.

Nystagmus is compensatory eye movements keeping the visual object on the same place in the retina, while moving the head. The direction of the nystagmus is named by the direction of the quick phase. Nystagmus due to an asymmetry of the peripheral vestibular system is usually unidirectional, with the quick phase beating away from the hypoactive labyrinth. The intensity of the nystagmus increases when the eyes are turned in the direction of the quick phase. Vestibular nystagmus is suppressed by visual fixation. CNS-elicited nystagmus does not usually change in intensity with the removal of fixation, in contrast to peripheral\textsuperscript{85}.

Figure 4. The Vestibulo-ocular reflex (permission by Hydèn D).
The somatosensory system

This system provides information from mechanoreceptors, muscles, joints and skin receptors to register gravity, motion and the position of body parts relative to one another. Proprioception from the neck is of particular importance. Somatosensory input from the neck, activated by changes in head orientation, can influence the distribution of the postural tone in the trunk and the limbs. Input from the visual and vestibular systems also influences the postural tone. Vestibular inputs alter the distribution of postural tone in the neck and limbs and have been referred to as the vestibulo-colic and vestibulo-spinal reflexes. The somatosensory system provides the CNS with position and motion information about the body’s position with reference to the surface. Walking is more complex than standing, but the process of maintaining balance is similar. The postural responses are triggered by muscle proprioceptive inputs, involving peripheral sensory and motor regions of the brainstem and cortex. Automatic postural responses are organized into two distinct movement patterns about the ankle and hip.

Aging

The aging process interferes with every part of the balance systems. There is a progressive loss of function in the vestibular, visual and somatosensory systems which can contribute to balance deterioration. In 1973, Rosenhall found a 20% mean reduction in the hair cell population of maculae and 40% of the crista ampullaris over the age of 70 years. An age-related reduction in proprioception was demonstrated by Skinner et al. in 1984 and a similar reduction in muscle strength has been found. Longitudinal tests of decline in vestibular function correlate with decline in gait and balance on testing. It is likely that both the central and peripheral vestibular pathways play a role in age-related decline in balance. A slow reaction time in older adults may be due to changes in the central and peripheral nervous systems.
Examinations of vestibular function

Making a diagnosis in patients with dizziness is dependent on case history and familiarity with examination techniques. An examination of possible nystagmus is fundamental and it is easier to observe in the dark while the ocular fixation is inhibited. The best tool is videonystagmoscopy (VN), a diagnostic system for recording, analyzing and reporting involuntary eye movements, using video imaging technology. Gaze nystagmus is evaluated in the mid-position and 30 degrees to the sides, up and down. The degrees of nystagmus can be determined using Alexander’s law which states that the first degree of nystagmus is present only with gaze in the direction of the fast component. A second degree is present in the mid-position and gaze in the direction of the fast component and third-degree nystagmus is present in all directions. The head-shaking test, the head is shaken vigorously for about 10-30 cycles and then stopped. The optimal way to evaluate the head-shaking test is with VN. The head-shaking-induced nystagmus test is a useful aid in the diagnosis of unilateral vestibular dysfunction and when a horizontal nystagmus is found, the quick phase of the nystagmus is directed towards the healthy ear. The head-impulse test is a fairly new test which today is a widely accepted clinical sign that indicates large asymmetry or canal paresis.

Electronystagmography (ENG)

The recording technique used in ENG is a bio-electrical signal. The eyeball has dipolar orientation, like a battery, with the cornea being positively polarized and the retina negatively polarized. This standing potential is propagated through the eyes by volume conduction which is capable of being recorded with conventional surface electrodes which are placed horizontally and vertically of each eye. This technique allows electrophysiological recordings of the eye movements, such as spontaneous nystagmus, smooth pursuit, saccade, optokineti testing and nystagmus created by caloric testing.

Caloric test

In caloric testing, irritation of the external auditory canal with 30°C cool and 44°C warm water is used to determine the excitability of the individual horizontal canals. Caloric testing aims to detect the loss of the labyrinthine function primarily in the horizontal canal. To quantify peripheral vestibular function, the maximum velocity of the induced eye movements should be measured. To assess and compare caloric excitability, the Henriksson formula is often used to compare the function of both labyrinths. A value of > 20% asymmetry is considered pathological and
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Positional tests

Position testing is used to identify whether otoconia has been displaced into the semicircular canals causing benign paroxysmal positional vertigo (BPPV). Otoconia dispersed in the endolymph makes the semicircular canals sensitive to positional changes of the head. The abnormal signal from the cupula results in nystagmus and vertigo, nausea and sometimes vomiting.

Dix-Hallpike test

In the Dix-Hallpike test, the examiner stands at the side of the patient and rotates the head 45° to this side. The patient is brought from sitting to the supine ear-down position and the neck is extended about 30°. The latency and duration of nystagmus are noted. A positive response is considered to be an intense vertigo accompanied in most cases by nystagmus which starts after a short latency. After resolution of the subjective vertigo and the nystagmus, the patient is slowly brought back to an upright position and a reversal of the nystagmus may be observed. If the Dix-Hallpike test is repeated with fatigued response, the diagnosis is further confirmed (Fig. 5).
Side-lying test
Dix-Hallpike can be difficult to perform in the elderly, due to the limited range of motion when extending the neck, vertebral-basilar insufficiency and cervical spondylosis. The side-lying test stimulates the posterior semicircular canal while the head and neck are fully supported on the examination table. To perform the side-lying test, the patient is seated in an upright position and the head is turned 45° away towards the side. The patient is rapidly moved to a side-lying position and stays in this position for two minutes or until the vertigo disappears. The latency, duration and direction of the nystagmus are noted27.

Balance Assessment
Static balance tasks have been used to clinically document balance function. Romberg, single leg stance and sharpened Romberg are often included in a static balance test battery and can be performed with eyes open or closed14,23.

Dynamic balance tests includes different walking tests where the speed is measured15,89,90. One gait task is walking while moving the head, either to the left and right or up and down. Other gait task are tandem walking and walking in a figure of eight52,76,158. Dynamic gait index (DGI)139 and “Stop walking when talking”96 have also been used to evaluate dynamic balance.

Definitions of vertigo, dizziness and unsteadiness
Vertigo and dizziness are often described as synonymous, but this can be questioned163. Vertigo is in this thesis defined as an illusion of movement130,163. Dizziness is in this thesis defined as a sensation of a
dizziness, balance and rehabilitation ...  lena kollén

Figure 5. Dix-Hallpike test – reprinted from CMAJ, 30 September 2003; 169(7), page(s) 681-693, with the permission of the publisher. © 2003 Canadian Medical Association.

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Definitions of vertigo, dizziness and unsteadiness
Vertigo and dizziness are often described as synonymous, but this can be questioned. Vertigo is defined in this thesis as an illusion of movement. Dizziness is defined as a sensation of a disturbed relationship with surrounding objects in space, without a feeling of vertigo. Unsteadiness is defined as the feeling of being unstable when sitting, standing and walking.

Benign paroxysmal positional vertigo (BPPV)
This disease was first described as an otolith disease in 1921 by Bárany and in 1952 by Dix and Hallpike. The disease has also been named benign positional vertigo, paroxysmal positional vertigo and paroxysmal positional nystagmus.

The lifetime prevalence is 3.2% in females and 1.6% in males and the 1 year incidence is 0.6%. Another study from Japan reported a lower incidence of BPPV of 0.01%. Bath et al. found that 65% of patients in a dizzy clinic suffered from a vestibular disorder and the most common diagnosis was BPPV. Decreased quality of life in elderly and reduced activities of daily life, falls and depression have been reported in conjunction with BPPV. Different etiologies of BPPV have been suggested and, in 1969, Schuknecht proposed the theory of cupulolithiasis means that the otoconia interfered with the cupula of the posterior semicircular canal. In 1979, Hall et al. proposed the theory of canalolithiasis. This theory suggested that the otoconia floats freely in the endolymph. In 1985, McClure et al. introduced the mechanism for BPPV of the horizontal semicircular canal. Finally, in 1994, Brandt et al. reported BPPV of the anterior semicircular canal. Today, BPPV is thought to be caused by either canalolithiasis or cupulolithiasis and all three semicircular canals may be affected. The majority of all cases are located in the posterior canal.
Different causes of BPPV have been suggested, such as head trauma, Menière's disease and vestibular neuritis, along with other inner-ear diseases that detach otoconia. Migraine has also been associated with BPPV. In most patients with BPPV, the etiology is labeled idiopathic. It has also been suggested that hormonal factors play a role as well as osteopenia/osteoporosis. The classical symptoms of BPPV include acute attacks of vertigo when changing position, rolling and lying down or getting up, when the neck is moved backwards or flexed forwards. The vertigo is described as severe rotatory vertigo or a milder floating sensation. Approximately 50% also report subjective imbalance between the classic episodes of BPPV. Postural instability has been reported in several studies. The diagnosis of BPPV is confirmed by a pathological Dix-Hallpike test. The prognosis for BPPV is usually good and, in many cases, there is a spontaneous remission within 3 months, but the symptoms may be more persistent in the minority of subjects. Treatment of BPPV started in the 1980s using physical therapy exercises (Brandt & Daroff exercises), which were designed to
reduce the symptoms by habituation. The aim was thought to provoke the symptoms and thus develop central compensatory mechanisms. Brandt and Daroff exercises start from a sitting position, after which the patient quickly lies down on one side and remains in this position until all the symptoms of vertigo have disappeared (maximum 30 s). The patient is then instructed to sit up and again wait for any symptoms to abate. The same procedure is repeated on the opposite side. The exercises are repeated three times in one session, twice a day, until no further symptoms are provoked. Maneuver treatments were developed in the 1980s by Semont and Epley. The Semont maneuver is based on the cupulolithiasis and canalolithiasis theory. Through a rapid change of the head position, the otoconia moves through the common crus and finally enters the utriculus. In the Semont maneuver, the patient is in the sitting position with his/her head turned away from the affected side. The patient is then quickly put into a position lying on the affected side, with the face turned upwards. After about 5-10 min, the patient is quickly moved back through the sitting position to the opposite side with the face now facing downwards. The patient remains in this position for about 10 min, before slowly being brought back to the sitting position (Fig. 7). The Epley maneuver is also called canalith repositioning. The maneuver begins with the patient sitting. The head is rotated 45° to the affected ear side. The patient is then rapidly moved from a seated position to a supine position, with the affected ear down (first part of the Dix-Hallpike test). The patient’s neck is extended approximately 20° and supported by the examiner. The patient stays in this position for two minutes, after which the head is slowly moved to the healthy side and, when the nose and head are straight up, the patient stays in this position for 30 seconds. The patient rolls over to the healthy side with his/her nose down and stays in this position for two minutes. Finally, the patient is brought up slowly to the sitting position.
BPPV is usually a very typical disorder but there are some differential diagnoses to consider. When a CNS lesion is the cause of BPPV-like vertigo, the nystagmus is usually stronger and more persistent and might change direction during the Dix-Hallpike test. When repeating the Dix-Hallpike tests, the vertigo and nystagmus do not abate. Cervical vertigo may produce symptoms resembling BPPV, but the vertigo may be triggered by rotation of the head relative to the body.

**Acute Unilateral Vestibular Loss (AUVL)**

The disease was named vestibular neuronitis in 1949 by Hallpike, who reported a number of cases with acute onset of vertigo without cochlear involvement. It has also been called unilateral peripheral vestibular disorder, acute unilateral vestibular neuritis or neuronitis and has been attributed to a subtle viral infection. The multiplicity of terms reflects the uncertainty of the pathology. AUVL is one of the most common causes of...
vestibular vertigo, with an incidence of 3.5 per 100,000/year\textsuperscript{149}. AUVL can affect both adults and children, but it peaks between 40-50 years of age\textsuperscript{134}. Exact anatomical location is not known, the vestibular end organ, the inferior and/or superior vestibular nerve and brainstem structures (vestibular nucleus) have been suggested\textsuperscript{83, 110, 154}. The causes of the disease are not known, although it has been suggested that the causes might be inflammatory, ischemic or immunological\textsuperscript{6, 21, 149}. The symptoms are an acute onset of an intense sensation of rotation (vertigo), aggravated by head motion and change of position. Balance is impaired, with difficulty in standing and walking and a tendency to fall towards the affected side. There is an absence of auditory and other neurological symptoms. Autonomic symptoms include nausea, vomiting, anxiety, pallor and sweating\textsuperscript{6}. One important sign of AUVL in the acute stage is rotatory vertigo and a spontaneous horizontal nystagmus towards the healthy ear with a rotational component\textsuperscript{51, 130, 149}. The horizontal nystagmus may be due to the involvement of the horizontal semicircular canal and, along with the torsional component, this is probably a sign of a disruption to vestibular influx, reflecting a “vestibular neuronitis”\textsuperscript{51, 149}. The spontaneous nystagmus is typically reduced in amplitude during fixation due to visual suppression of the VOR\textsuperscript{149}. It has been suggested that AUVL involves the superior part of the vestibular nerve, whereas the inferior vestibular nerve is spared, but both the superior and inferior part can be affected together\textsuperscript{3, 39, 149}.

An examination including assessment of spontaneous nystagmus, severity of imbalance and presence or absence of associated neurological signs is necessary. To confirm the diagnosis, an ENG with binaural, bithermal caloric test is helpful in order to identify the possible pathology in the superior vestibular nerve while vestibular-evoked myogenic potentials (VEMP) can be used to investigate the integrity of the inferior vestibular nerve\textsuperscript{108}. The recurrence rate of AUVL is thought to be low\textsuperscript{63, 101}. The vestibular function can recover completely, partially or not at all\textsuperscript{51}.

It has been suggested that recovery from AUVL is a result of multiple mechanisms, where both neural plasticity and functional changes might be involved (adaptation, habituation, compensation and substitution\textsuperscript{18}). After recovering from AUVL, a new attack of spontaneous nystagmus can occur in the opposite direction (“erholungsnystagmus”), where the centrally compensated lesion regains its function\textsuperscript{149}. Clinical studies have shown that vestibular compensation occurs more rapidly and is more complete if vestibular rehabilitation starts early after the occurrence of a vestibular lesion\textsuperscript{6, 147, 149}.
Vestibular rehabilitation

Vestibular rehabilitation was first described in the 1940s (Cawthorne 1945; Cooksey, 1946), when an exercise program was developed and published. The first group exercise program which was designed to reduce dizziness in people with head injuries. The exercise program incorporated eye-head exercises to stimulate the semicircular canals and the otolith organs and the program was initiated at an early stage after the onset of symptoms. Dix suggested home exercises for 5 minutes, 3 times a day for up to 1 to 3 months until the symptoms were resolved. In the 1980s, Norre et al. suggested habituation therapy to provoke dizziness. The Brandt and Daroff exercises were developed in the 1980s to treat patients with motion-provoked dizziness. Vestibular rehabilitation therapy has been proven useful in patients with peripheral and central vestibular disorders and is more effective in peripheral disorders compared to central vestibular disorders. In 2004, Hall et al. demonstrated that vestibular rehabilitation in unilateral vestibular hypofunction is effective in reducing the risk of fall. Today, the term “vestibular rehabilitation” is used for different exercises to reduce symptoms, such as dizziness, vertigo and impaired balance, and today these exercises are primarily administered by physiotherapists. Vestibular rehabilitation is designed to promote habituation, adaptation and compensation for deficits related to a wide variety of balance disorders. There is no single specific protocol for vestibular rehabilitation, but rather a program of therapy which is developed on basis of the underlying diagnosis. The goal of vestibular rehabilitation is to make the patient free of symptoms of vertigo, dizziness and unsteadiness. Secondary goals are to reduce anxiety and depression by restoring functional capacity.
Aims of the thesis

The studies presented in this thesis were designed to address the following aims:

Study I
- To investigate spontaneous and head-shaking nystagmus, caloric asymmetry, vertigo and duration of sick leave at disease onset, after one and six months in patients with AUVL who had undergone vestibular rehabilitation.
- To study the relationship between the reduction of spontaneous and head-shaking nystagmus, caloric asymmetry, vertigo, age and the duration of sick leave in patients with AUVL after six months.
- To study whether the initial signs of nystagmus, caloric asymmetry and vertigo could predict return to work.

Study II
- To evaluate static and dynamic balance in patients with AUVL six months after disease onset who had undergone vestibular rehabilitation,
- To assess hypertension, headache, disturbed sleep and physical exercise habits in patients with AUVL.
- To compare the above mentioned parameters with a healthy reference group.

Study III
- To evaluate the long-term effects (12 months) of the Semont maneuver and Brandt-Daroff exercises in patients with long-lasting BPPV (> 3 months) with reference to static, dynamic balance performance, vertigo, physical exercise habits, headache, neck-and shoulder pain, sleeping habits and sick leave.

Study IV
- To investigate the prevalence of dizziness impaired balance and BPPV in a population of 75-year-old subjects and to compare elderly persons with and without BPPV concerning static, dynamic balance and dizziness.
Material

Study I

The patients were recruited consecutively from otolaryngology/audiology departments at three hospitals in the western part of Sweden (population 1.6 million). Inclusion criteria: Acute unilateral vestibular loss with vertigo, including vomiting, unidirectional spontaneous nystagmus and a caloric asymmetry of ≥20%. Vestibular rehabilitation should have been initiated within 48 h after disease onset. Exclusion criteria: Age over 70 years, disabilities preventing the performance/execution of the training program and inability to understand the Swedish language. Forty-four patients were originally included. Two patients were excluded due to a subsequent diagnosis of brainstem tumor. Fifteen patients did not complete all the tests and were therefore not included in the analysis. As a result, 27 patients (14 women, 13 men, mean age 52 years, range 16-70 y) were finally followed up and included in the study.

Study II

Forty-two patients, the same patients as primarily included in study I, with a mean age of 51 years (16-70 y), 18 (43%) women and 24 (57%) men, were included in the study. They had all undergone vestibular rehabilitation initiated within 48 h after disease onset. The results of static and dynamic balance were compared with those of an age- and gender-matched reference group, which consisted of 56 healthy subjects with no previous experience of vertigo (28 women, 28 men; mean age 52 years, range 28-63 y).

Study III

Seventeen patients 13 women and four men were included in the study. The age ranged from 31-66 years, with a mean of 52 years. They were consecutively recruited by referral to the Department of Audiology at Sahlgrenska University Hospital, Gothenburg, Sweden during the period of year 2000 to 2004. Inclusion criteria: A typical history of BPPV vertigo for more than three months and a clinical presentation of nystagmus and vertigo during the Dix-Hallpike test. Only patients with posterior vestibular canal BPPV were included. Exclusion criteria: Patients over 70 years of age and subjects unable to understand the Swedish language. The mean duration of symptoms was 25 months, with a median of 12 months (range 3-260 months).
Study IV

H70 is a combination of longitudinal and cross sectional population based studies emanating from Gothenburg in Sweden\(^{125}\). The participants were chosen through the systematic sampling of 75-year-olds, born in 1930, based on date of birth, in a Gothenburg urban population. Exclusion criteria were inability to understand the Swedish language. One thousand three hundred and thirty-two persons were invited to take part in the study, of which 675 (398 women and 277 men) agreed to participate and complete the questionnaire. Of the 675 persons, 571 (332 women and 239 men) both completed the questionnaire and performed the test battery. The remaining 104 persons, who only answered the questionnaire but did not participate in the tests, did so mainly due to mobility problems or tiredness.

Methods

An overview of the methods used in the different studies is shown in Table 1.

<table>
<thead>
<tr>
<th>Study</th>
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<td>Dix-Hallpike test</td>
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*Dizziness, balance and rehabilitation ...  Lena Kollén*
Questionnaires

Questionnaires were used for data collection about general health, physical activity, employment, sick leave and subjective symptoms of vertigo, dizziness and impaired balance. The questions about general health comprised antihypertensive medication, headache (yes or no) and sleeping habits (<6, 6-8 or >8 h/night). Sleep duration < 6 hours/night was classified as disturbed sleep (Study II and III).

Questions about hearing, tinnitus, vision, trouble with neck and shoulder pain, smoking and alcohol were added in Study III. These questions were answered by the alternatives “yes” or “no”.

Five questions about physical exercise habits and activity level were stated. The answer alternatives were A. No exercise; B. Mostly sitting, easy housework; C. Light physical exercise, housework; D. Heavy physical exercise, 1-2 h/week; E. Heavy physical exercise, 2-3 h/week (Study II and III). In Study III, the questionnaire included questions about activity level at disease onset and after 12 months. If activities had changed a follow up question was put to determine which activity had changed.

Questions concerning degree of employment had the response alternatives, full time, part time, working at home, retired, unemployed and sick leave (Study I and III).

Dizziness/vertigo (study I, II and III) was rated using a visual analog scale (VAS), with four different questions; A) Dizziness/vertigo during movements and certain positions; B) Dizziness/vertigo at any time, unrelated to movements; C) Unsteadiness when standing and walking; D) Experience of constant rotatory vertigo. The VAS ranged from no symptoms (0 mm) to worst possible symptoms (100mm).

In study IV the questionnaire comprised the following six questions: 1. Do you have any problems with dizziness or impaired balance? 2. Do you experience unsteadiness when walking outdoors? 3. Do you have problems with vertigo/dizziness when turning in bed or bending backwards/forwards? 4. Do you experience vertigo/dizziness when sitting or lying still? 5. Do you experience constant vertigo/dizziness? 6. Have you consulted a doctor because of dizziness/vertigo? The alternatives for questions 1-4 were a) seldom, b) sometimes, c) frequently and, in questions five and six, the alternatives were yes/no.

Videonystagmoscopy (VN) (I, II and III)

The vestibular function was evaluated by videonystagmoscopy (SMI Binocular Video Frenzel System) or Frenzel glasses. Goggles equipped with two infrared charged couple devices (C-A Tegnér AB), which
Questionnaires were used for data collection about general health, physical activity, employment, sick leave and subjective symptoms of vertigo, dizziness and impaired balance. The questions about general health comprised antihypertensive medication, headache (yes or no) and sleeping habits (<6, 6-8 or >8 h/night). Sleep duration < 6 hours/night was classified as disturbed sleep (Study II and III). Questions about hearing, tinnitus, vision, trouble with neck and shoulder pain, smoking and alcohol were added in Study III. These questions were answered by the alternatives "yes" or "no". Five questions about physical exercise habits and activity level were stated. The answer alternatives were A. No exercise; B. Mostly sitting, easy housework; C. Light physical exercise, housework; D. Heavy physical exercise, 1-2 h/week; E. Heavy physical exercise, 2-3 h/week (Study II and III). In Study III, the questionnaire included questions about activity level at disease onset and after 12 months. If activities had changed a follow up question was put to determine which activity had changed. Questions concerning degree of employment had the response alternatives, full time, part time, working at home, retired, unemployed and sick leave (Study I and III).

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Videonystagmoscopy (VN) (I, II and III) The vestibular function was evaluated by videonystagmoscopy (SMI Binocular Video Frenzel System) or Frenzel glasses. Goggles equipped with two infrared charged couple devices (C-A Tegnér AB), which excluded the visual cues, were used to examine spontaneous and head-shaking nystagmus. Spontaneous nystagmus was assessed with the eyes directed forward, while head-shaking nystagmus was assessed after > 15 vigorous head-shaking movements, moving the patient’s head at about 3-4 Hz in the seated position19. Five different positions were assessed (i.e. looking straight ahead, to the right, to the left, looking up and down and head-shaking nystagmus).

Electronystagmography (ENG) and caloric testing (I and II) Electronystagmography (ENG, Linköping University, Somedic, 1996) was used. Gaze nystagmus was measured with an ocular deviation of 30 degrees from the neutral position. Saccade tests and smooth pursuit tests were also performed but are not reported. Bithermal, bilateral caloric testing (250 ml at 30° and 44°) was performed by irrigating the external auditory canal for approximately 30 seconds. The velocity of the slow phase of the induced nystagmus was calculated according to Henriksson’s method57. An inter-aural difference of >20% was considered pathological130.

Static balance tests (II, III and IV) Romberg test with eyes closed was performed in a standing position with the arms at the sides and without shoes. The test was terminated when the subjects lost their balance by moving one or both feet, performed compensatory movements, or opened their eyes. The best of three trials was recorded in seconds and the maximum time was 60 seconds14. Sharpened Romberg with eyes open (SREO) and eyes closed (SREC) were performed as above but with the heel of the dominant foot directly in front of the toe of the non-dominant foot. The test was interrupted when the subjects lost their balance by moving one or both feet, performed compensatory movements, or opened their eyes during the eyes-closed tests. The best of three trials was recorded in seconds and the maximum time was 30 sec23, 158. Leg dominance was determined by the Harris test34, as the leg used for the performance of at least two of the following pantomime activities: kicking a ball, stamping out a fire and stepping up a step, were used in the sharpened Romberg test and standing on one leg14.

The test standing on one leg with eyes open (SOLEO) and eyes closed (SOLEC), were performed standing on the dominant leg, with the knee of the other leg flexed at an angle of 45 degrees, with a slight distance maintained between the legs and with the arms at the sides. The test was terminated when the subjects lost their balance by moving one or both feet,
performed compensatory movements, or opened their eyes during the eyes-closed tests. The best of three trials was recorded in seconds and the maximum time was $30\text{ sec}^{23,158}$.

In study IV static balance was tested as the ability to stand on one leg (right as well as left) without shoes, for a maximum of 30 seconds. The hip joint of the non-weight bearing leg was in the neutral position and the knee flexed to approximately 90 degrees, hands behind their back and looking straight ahead. The test was interrupted if the subject moved from the standardized position. Three trials for each leg were allowed and the best result was used for analysis$^{41}$.

**Dynamic balance tests (II, III and IV)**

The dynamic balance tests registered the speed in meter/seconds and the number of steps. The patient was instructed to walk from a line at his/her normal speed. The stopwatch was started at “GO” in the instruction “Ready steady GO” and the watch was stopped when the first foot passed over the line$^{15}$. The dynamic balance tests comprised:

- Walking 10 meters without head movements$^{15}$
- Walking 10 meters while repeatedly moving the head to the left and right side (horizontal head movements) in connection with each step$^{89,90}$.
- Walking 10 meters while repeatedly moving the head up and down (vertical head movements) in connection with each step$^{89,90}$.

**Dix-Hallpike test (III)**

A Dix-Hallpike test was performed using videonystagmoscopy. The latency and duration of the nystagmus were recorded in seconds and registered. The Dix-Hallpike test was performed both to verify the diagnosis and to evaluate treatment efficacy after one, six and 12 months. The Dix-Hallpike test was made on both sides to exclude bilateral BPPV or anterior or horizontal BPPV$^{31}$. 
Side-lying test (IV)
The subject’s head was turned with the nose pointed 45° away from the tested ear. The person was moved from the sitting position to the side that was tested with the eyes open. This position was maintained for at least two minutes. The subject was returned to the sitting position and the same procedure was performed on the other side. The vertigo was registered as “yes” or “no”, and the side, the duration of vertigo and the occurrence of nystagmus were noted.

Procedures

Study I
A preliminary diagnosis of AUVL was made by an ENT specialist at the emergency room and included the examination of the ear, nose and throat, otoneurological testing and the evaluation of nystagmus using videonystagmoscopy equipment or Frenzel glasses (first examination). The patients were given information about their preliminary diagnosis and the purpose of the training program, which started within 48 h after the disease onset. Electronystagmography (ENG) including a caloric test was performed as soon as possible after disease onset (median four days) and after six months by an audiologist. At discharge from hospital (after 1-7 days), the physiotherapist assessed spontaneous and head-shaking nystagmus and the first questionnaire was completed (second examination). After one month, another assessment of nystagmus was performed and the second questionnaire was completed. A follow-up six months after disease onset included an assessment of nystagmus, the completion of the third questionnaire and another examination of the ENG (ENG 2) (Fig. 8).

The instructions for vestibular rehabilitation were given both verbally and writing by the physiotherapists B.B., L.K. (authors). The exercises consisted of repeated horizontal and vertical eye movements at different speeds while keeping the head still and repeated horizontal and vertical head movements while keeping the eyes fixed. Each set of exercises was gradually prolonged up to 15 seconds and the speed was increased in order to increase or arouse the patient’s sensation of vertigo or dizziness. Other exercises included following moving objects with the eyes when standing and during walking. The exercises included maintaining balance with and without support while sitting, standing and walking. Balance training in standing was performed on even and uneven surfaces, with the eyes open and closed, with varying bases of support, with and without simultaneous
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head, trunk, arm and leg movements. Walking was performed with varying bases of support; walking on a line, with and without simultaneous head movements; turning 180 and 360° at different speeds; walking backwards, sideways and with the eyes open and closed; walking up and down stairs; and walking on and over objects. The aim of the exercises was to normalize reactions induced by fast movements of the head. This was induced by turning in bed, sitting up/lying down and bending forwards and up again. Patients were also encouraged to walk outdoors, if possible on uneven ground, and to resume their leisure and physical exercise activities as soon as possible. The exercises were designed to be challenging to the patients, and the training program was individualized, so the degree of training was different for each patient. The patients continued to exercise as long as the symptoms remained, either at home or in an out-patient physiotherapy clinic for one month.

ENT- specialist examination | VN | Questionnaire | VN | Questionnaire | VN | Questionnaire
|------------------------|---|--------------|---|--------------|---|--------------
| Rehab begins           |   |             |   |             |   |             
| Disease onset          | <48 h | <1 week | one month | six months 
| 1:st examination       |   |             |   |             |   |             
| 2:nd examination       |   |             |   |             |   |             
| 3:rd examination       |   |             |   |             |   |             
| 4:th examination       |   |             |   |             |   |             

VN=Videonystagmoscopy assessment

Figure 8. The flow chart for study I.

**Study II**

The evaluation was performed six months after the onset of AUVL and after vestibular rehabilitation (see Study I) by the physiotherapists B.B., L.K. The tests and the questionnaire were completed on the same occasion by all patients. The healthy reference group without history of dizziness, vertigo or unsteadiness did not answer the questionnaire.

**Study III**

Initially, the patients were interviewed about vertigo, the onset of symptoms and provoking factors. Videonystagmoscopy (VN) was performed in the sitting position to assess possible nystagmus which may indicate other diseases. A Dix-Hallpike test was performed using VN to confirm BPPV. Static and dynamic balance was assessed, the patients were
asked to fill in a questionnaire and finally time for a follow-up appointment was made. Static and dynamic balance tests were performed before treatment and at the follow-up. Depending on the outcome of the treatment the first follow-up was within 1-2 months, the second within 6-7 months and the third within 12-13 months. The questionnaire was answered with the same interval (Fig. 9). Treatment with the Semont maneuver was performed one week after initial contact. The Semont’s maneuver was performed as described in the introduction and after the maneuver had been performed, the patients were instructed to wear a soft cervical collar for 48 hours, as a reminder not to move their head up and down, and to lie in a semi-recumbent position for the first two nights. The patients were contacted after two weeks by telephone to explore whether their symptoms of vertigo remained. The patients who complained about still having persistent symptoms were scheduled for a new outpatient appointment to confirm the possible presence of BPPV. If the Dix-Hallpike test was positive, a second Semont maneuver was performed at the same time. Two weeks after the second Semont maneuver, the patients were contacted again and, if no vertigo symptoms were present, a new examination was performed one month after the second Semont maneuver. Patients who still suffered from BPPV symptoms after two Semont maneuvers were given verbal and written instructions about Brandt & Daroff exercises. The exercises were performed at home, three times daily, until the symptoms disappeared. The patients who performed Brandt & Daroff exercises were followed up one month after commencing the exercises. All follow-up appointments included Dix-Hallpike static/dynamic balance tests and a questionnaire.
**Study IV**

The participants were tested during an ordinary study visit in the H70 study. Static balance tests (SREO, SREC, SOLEO), dynamic balance tests (walking 10 meters with and without horizontal head movements) were performed. A questionnaire which comprised six questions about dizziness and impaired balance was completed. Four specially, (by LK and CM), trained nurses performed the tests. All tests and questionnaires were administered on the same occasion. A modified Dix-Hallpike maneuver (side-lying test) was performed and it was considered pathological (BPPV) if the subject experienced vertigo and/or nystagmus. All together the study examination was performed within 60 minutes.
Statistical analysis

Study I
The statistical analysis was performed using SPSS (SPSS base 10.1 for Windows: user’s guide. Chicago, IL: SPSS; 2000). Changes within groups were tested with Wilcoxon’s signed rank test for continuous variables and the sign test for dichotomous variables. Chi-square test for difference in proportion between ENG onset and after 6 months. All correlation analysis were performed using Spearman’s non-parametric correlation test. Comparison between the groups was conducted using Mann-Whitney U-test.

Study II
The statistical analysis was performed using (SPSS) 10.1. Wilcoxon’s rank sum test was used to analyze differences between the groups. Chi-square test for difference in proportion between the two groups was used to compare antihypertensive medication, headache and sleeping habits.

Study III
The Statistical Package for Social Sciences (SPSS) 10.1 was used for descriptive statistics. Wilcoxon’s signed rank test was used to analyze changes between “before treatment” and “follow-up”.

Study IV
Analysis was performed by using a statistics program package developed at the Department of Geriatrics at Gothenburg University (GIDSS for Windows). The chi-square test for differences in proportion between two groups and the chi-square for trends between three or more groups were used. There was a binomial test for the distribution of problems between the right and left ear. For dependent variables in a linear scale, a T-test was used for testing differences between groups and linear regression when adjusting for gender, body height and body weight. For dichotomized dependent variables, a binary logistic regression model was used. All the tests were two-tailed and conducted at the 5% significance level.
Ethical considerations

The studies were carried out in accordance with the Helsinki Declaration and approved by the local ethics committee of Gothenburg University in 1998 (Studies I-III) and by the regional ethics committee in Gothenburg (Dnr S 227-00) (Study IV) in 2004. In all the studies, the subjects received both oral and written information about the study and gave their written consent and they were informed of their right to terminate their participation at any time.

Results

Study I

The spontaneous nystagmus decreased rapidly after disease onset, whereas head-shaking nystagmus remained to a higher extent after one month. At six months, none had spontaneous nystagmus but 19% showed head-shaking nystagmus (Table 3). At disease onset, the mean asymmetry of the caloric test was 68% (range 20-100%), after six months there was a decrease to 37%. Twenty-six % of the patients displayed 100% asymmetry at disease onset and, at 6 months, 7% still displayed unilateral caloric areflexia. At six months, 41% had normalized caloric response (Table 4). After six months, the persistence of spontaneous nystagmus was related to a greater degree of asymmetry. Subjective symptoms, such as dizziness and unsteadiness, assessed by the VAS, showed a significant decrease between onset and the one-month examination. A positive relationship between the subjective feeling of unsteadiness when standing and walking and the occurrence of sick leave at one and six months was found and unsteadiness when standing and walking was also positively correlated to the degree of caloric asymmetry after six months ($\rho = 0.71$, $p < 0.01$).
Ethical considerations

The studies were carried out in accordance with the Helsinki Declaration and approved by the local ethics committee of Gothenburg University in 1998 (Studies I-III) and by the regional ethics committee in Gothenburg (Dnr S 227-00) (Study IV) in 2004. In all the studies, the subjects received both oral and written information about the study and gave their written consent and they were informed of their right to terminate their participation at any time.

Results

Study I

The spontaneous nystagmus decreased rapidly after disease onset, whereas head-shaking nystagmus remained to a higher extent after one month. At six months, none had spontaneous nystagmus but 19% showed head-shaking nystagmus (Table 3). At disease onset, the mean asymmetry of the caloric test was 68% (range 20-100%), after six months there was a decrease to 37%. Twenty-six % of the patients displayed 100% asymmetry at disease onset and, at 6 months, 7% still displayed unilateral caloric areflexia. At six months, 41% had normalized caloric response (Table 4).

After six months, the persistence of spontaneous nystagmus was related to a greater degree of asymmetry. Subjective symptoms, such as dizziness and unsteadiness, assessed by the VAS, showed a significant decrease between onset and the one-month examination. A positive relationship between the subjective feeling of unsteadiness when standing and walking and the occurrence of sick leave at one and six months was found and unsteadiness when standing and walking was also positively correlated to the degree of caloric asymmetry after six months (rho=/0.71, p</0.01).

Table 3. Illustrates the number and percent for spontaneous nystagmus, head-shaking nystagmus and sick leave. Mean percent for caloric asymmetry and mean in mm for VAS at disease onset, after 1 and 6 months.

<table>
<thead>
<tr>
<th></th>
<th>Disease onset</th>
<th>One month</th>
<th>Six months</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous nystagmus</td>
<td>13 (48%)</td>
<td>3 (11%)</td>
<td>0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>&lt;0.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Head-shaking nystagmus</td>
<td>24 (92%)</td>
<td>14 (54%)</td>
<td>5 (19%)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>&lt;0.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Caloric asymmetry %</td>
<td>68 (26.8)</td>
<td>37 (30)</td>
<td></td>
<td>&lt;0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Spontaneous nystagmus</td>
<td>5 (4.1)</td>
<td>0.3 (0.8)</td>
<td></td>
<td>&lt;0.001&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Subjective symptoms, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS A</td>
<td>34 (26.6)</td>
<td>17 (21.5)</td>
<td>7 (12.3)</td>
<td>&lt;0.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>VAS B</td>
<td>20 (26)</td>
<td>4 (8.3)</td>
<td>5 (17)</td>
<td>&lt;0.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>VAS C</td>
<td>44 (23.6)</td>
<td>14 (14.2)</td>
<td>12 (17)</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>VAS D</td>
<td>17 (24.6)</td>
<td>0.3 (1)</td>
<td>2 (10.4)</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sick leave</td>
<td>18 (95%)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5 (26%)&lt;sup&gt;e&lt;/sup&gt;</td>
<td>4 (22%)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>&lt;0.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>disease onset to one month; <sup>b</sup>one to six months; <sup>c</sup>disease onset to six months; p <0.05, p <0.01, p <0.001; VAS A: dizziness during movements and certain positions; VAS B: dizziness at any time, unrelated to movements; VAS C: unsteadiness when standing and walking; VAS D: experience of constant rotatory vertigo; <sup>d</sup>n = 26; <sup>e</sup>n = 19; <sup>f</sup>n = 18.
Table 4. The caloric response/asymmetry in percent measured by electronystagmography (ENG) numbers and percent at disease onset (ENG1) and after 6 months (ENG2).

<table>
<thead>
<tr>
<th></th>
<th>Asymmetry</th>
<th>Asymmetry</th>
<th>Normalized</th>
<th>Increased asymmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100%</td>
<td>20-99%</td>
<td>0-19%</td>
<td></td>
</tr>
<tr>
<td>ENG 1</td>
<td>7/27 (26%)</td>
<td>20/27 (74%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENG 2</td>
<td>2/27 (7%)</td>
<td>11/27 (41%)</td>
<td>11/27 (41%)</td>
<td>3/27 (11%)</td>
</tr>
</tbody>
</table>

**Study II**

The 42 patients were examined six months after the onset of AUVL and none of them displayed spontaneous nystagmus. Five of the 42 patients were on sick leave. The mean caloric asymmetry was 65% at disease onset (range 20-100%), decreasing to 35% after six months. The AUVL group and the reference group performed the Romberg test and SOLEO within normal ranges. Patients with AUVL showed impaired static balance, walked more slowly with and without head movements and took shorter steps compared to the reference group (Table 5). A general decrease in walking speed was found in both groups when walking with head movements. This decrease was however larger in the AUVL group. No differences in relation to sleeping and physical exercise habits, and headache were found between the groups. A significantly larger percentage of patients with AUVL (26%) used anti-hypertensive medication compared with the reference group (4%). VAS ratings for vertigo/dizziness/unsteadiness in the AUVL group were generally very low.
Table 4. The caloric response/asymmetry in percent measured by electronystagmography (ENG) numbers and percent at disease onset (ENG1) and after 6 months (ENG2).

<table>
<thead>
<tr>
<th>Asymmetry</th>
<th>ENG 1</th>
<th>ENG 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>7/27 (26%)</td>
<td>2/27(7%)</td>
</tr>
<tr>
<td>20-99%</td>
<td>20/27 (74%)</td>
<td>11/27 (41%)</td>
</tr>
<tr>
<td>Normalized</td>
<td>0-19%</td>
<td>11/27 (41%)</td>
</tr>
<tr>
<td>Increased asymmetry</td>
<td>3/27 (11%)</td>
<td></td>
</tr>
</tbody>
</table>

Study II

The 42 patients were examined six months after the onset of AUVL and none of them displayed spontaneous nystagmus. Five of the 42 patients were on sick leave. The mean caloric asymmetry was 65% at disease onset (range 20-100%), decreasing to 35% after six months. The AUVL group and the reference group performed the Romberg test and SOLEO within normal ranges. Patients with AUVL showed impaired static balance, walked more slowly with and without head movements and took shorter steps compared to the reference group (Table 5). A general decrease in walking speed was found in both groups when walking with head movements. This decrease was however larger in the AUVL group. No differences in relation to sleeping and physical exercise habits, and headache were found between the groups. A significantly larger percentage of patients with AUVL (26%) used anti-hypertensive medication compared with the reference group (4%). VAS ratings for vertigo/dizziness/unsteadiness in the AUVL group were generally very low.

Table 5. Results of static and dynamic balance tests in subjects with AUVL compared to a reference group, mean X (SD).

<table>
<thead>
<tr>
<th></th>
<th>AUVL (n=42)</th>
<th>Ref.group (n=56)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X (SD)</td>
<td>X (SD)</td>
<td></td>
</tr>
<tr>
<td>SREC, s</td>
<td>23 (13)</td>
<td>28 (6)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>SOLEC, s</td>
<td>13 (12)</td>
<td>16 (11)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Walking 10 m, m/s</td>
<td>1.31 (0.78)</td>
<td>1.41 (0.13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of steps</td>
<td>0.70 (0.17)</td>
<td>0.89 (0.13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Walking 10 m with</td>
<td>1.20 (0.30)</td>
<td>1.33 (0.15)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>horizontal head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>movements, m/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of step with</td>
<td>0.67 (0.17)</td>
<td>0.87 (0.07)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>horizontal head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>movements 10 m, m/step</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking 10 m with</td>
<td>1.19 (0.24)</td>
<td>1.35 (0.13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>vertical head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>movements, m/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of step with</td>
<td>0.70 (0.12)</td>
<td>0.87 (0.05)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>vertical head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>movements 10 m, m/step</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AUVL: Acute unilateral vestibular loss group.
Ref. group: Reference group.
SREC: Sharpened Romberg eyes closed.
SOLEC: Standing on one leg eyes closed.

Study III

In the 17 patients with BPPV, the right side was affected in nine cases. Six of 17 patients were free from dizziness after a single Semont maneuver and 3/17 required a second Semont maneuver. Thus, 8/17 patients continued to suffer from BPPV and were subsequently given Brandt & Daroff exercises. Out of the eight patients who received Brandt-Daroff exercises, two were symptom free at one month. Eleven of the seventeen patients showed a negative Dix-Hallpike with no nystagmus at the one-month follow-up and, at the 6 and 12 month follow-up, the corresponding figure was 14/17 patients. An additional three patients were successfully treated with Brandt-Daroff exercises. The latency of nystagmus showed a mean of 4s before treatment and in the 3/17 patients with remaining symptoms, the latency was still 4 s at the 12-month follow-up. The duration of nystagmus was 21s before treatment (5-50s) reduced to 13s in the 3/17 patients with...
remaining problems after 12 months. This decrease of duration was
significant when comparing tests before and after 12 months. All patients
were normal in the Romberg test as well as SREO and SOLEO before
treatment and after 12 months. All the dynamic tests improved
significantly when comparing before treatment and the 12-month follow-
up (Table 6). The step length when walking with horizontal and vertical
head movements improved significantly (Fig. 10). On VAS, there was a
significant decrease in subjective vertigo, feeling of unsteadiness during
walking and standing (Fig. 11). Vertigo during certain movements showed
a larger decrease in patients cured primarily by the Semont maneuver.
Thirteen of the 17 patients had neck-shoulder pain prior to treatment. Ten
out of 17 continued to have pain after treatment. Prior to treatment, 16/17
had avoided lying on the affected side and moving the head backwards or
forwards. After 12 months, 14/17 patients had improved significantly and
returned to the same activities as before the disease.

<table>
<thead>
<tr>
<th>Test</th>
<th>Time (s)</th>
<th>speed (m/s)</th>
<th>Range  SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SREC</td>
<td>Before</td>
<td>15</td>
<td>(0-30)</td>
<td>(12)</td>
</tr>
<tr>
<td></td>
<td>1 month</td>
<td>20</td>
<td>(0-30)</td>
<td>(11)</td>
</tr>
<tr>
<td></td>
<td>6 months</td>
<td>20</td>
<td>(4-30)</td>
<td>(9)</td>
</tr>
<tr>
<td></td>
<td>12 months</td>
<td>22</td>
<td>(4-30)</td>
<td>(9)</td>
</tr>
<tr>
<td>SOLEC</td>
<td>Before</td>
<td>7</td>
<td>(0-26)</td>
<td>(6)</td>
</tr>
<tr>
<td></td>
<td>1 month</td>
<td>9</td>
<td>(0-30)</td>
<td>(8)</td>
</tr>
<tr>
<td></td>
<td>6 months</td>
<td>8</td>
<td>(3-30)</td>
<td>(7)</td>
</tr>
<tr>
<td></td>
<td>12 months</td>
<td>11</td>
<td>(2-30)</td>
<td>(10)</td>
</tr>
</tbody>
</table>

Walking speed

<table>
<thead>
<tr>
<th>Time</th>
<th>speed (m/s)</th>
<th>Range  SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>1.1 (0.83-1.43)</td>
<td>(0.20)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>1.2 (0.83-1.43)</td>
<td>(0.23)</td>
<td>&lt;0.05 a</td>
</tr>
<tr>
<td>6 months</td>
<td>1.3 (0.1-1.66)</td>
<td>(0.23)</td>
<td>&lt;0.05 b</td>
</tr>
<tr>
<td>12 months</td>
<td>1.3 (0.71-1.66)</td>
<td>(0.21)</td>
<td>&lt;0.01 c</td>
</tr>
</tbody>
</table>

Walking 10 m with horizontal head movements

<table>
<thead>
<tr>
<th>Time</th>
<th>speed (m/s)</th>
<th>Range  SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>1.0 (0.52-1.6)</td>
<td>(0.24)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>1.1 (0.71-1.43)</td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>1.2 (0.71-1.67)</td>
<td>(0.25)</td>
<td>&lt;0.01 b</td>
</tr>
<tr>
<td>12 months</td>
<td>1.2 (0.71-1.66)</td>
<td>(0.23)</td>
<td>&lt;0.01 c</td>
</tr>
</tbody>
</table>

Walking 10 m with vertical head movements

<table>
<thead>
<tr>
<th>Time</th>
<th>speed (m/s)</th>
<th>Range  SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>1 (0.55-1.25)</td>
<td>(0.20)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>1.2 (0.83-1.43)</td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>1.3 (0.71-1.67)</td>
<td>(0.16)</td>
<td>&lt;0.01 b</td>
</tr>
<tr>
<td>12 months</td>
<td>1.2 (0.71-1.42)</td>
<td>(0.19)</td>
<td>&lt;0.001 c</td>
</tr>
</tbody>
</table>

SREC, sharpened Romberg eyes closed; SOLEC, standing on one leg eyes closed. a The
difference between before and after 1 month. b The difference between before and after 6
months. c The difference between before and after 12 months.
Dizziness, balance and rehabilitation ... Lena Kollén

remaining problems after 12 months. This decrease of duration was significant when comparing tests before and after 12 months. All patients were normal in the Romberg test as well as SREO and SOLEO before treatment and after 12 months. All the dynamic tests improved significantly when comparing before treatment and the 12-month follow-up (Table 6). The step length when walking with horizontal and vertical head movements improved significantly (Fig. 10). On VAS, there was a significant decrease in subjective vertigo, feeling of unsteadiness during walking and standing (Fig. 11). Vertigo during certain movements showed a larger decrease in patients cured primarily by the Semont maneuver. Thirteen of the 17 patients had neck-shoulder pain prior to treatment. Ten out of 17 continued to have pain after treatment. Prior to treatment, 16/17 had avoided lying on the affected side and moving the head backwards or forwards. After 12 months, 14/17 patients had improved significantly and returned to the same activities as before the disease.

Table 6. Static and dynamic balance tests in patients treated with the Semont maneuver and Brandt-Daroff exercise.

<table>
<thead>
<tr>
<th>Test</th>
<th>Time (s)</th>
<th>Range</th>
<th>SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>speed (m/s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before treatment</td>
<td>15</td>
<td>(0-30)</td>
<td>(12)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>20</td>
<td>(0-30)</td>
<td>(11)</td>
<td></td>
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<tr>
<td>6 months</td>
<td>20</td>
<td>(4-30)</td>
<td>(9)</td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>22</td>
<td>(4-30)</td>
<td>(9)</td>
<td></td>
</tr>
<tr>
<td>SOLEC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before treatment</td>
<td>7</td>
<td>(0.26)</td>
<td>(6)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>9</td>
<td>(0-30)</td>
<td>(8)</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>8</td>
<td>(3-30)</td>
<td>(7)</td>
<td></td>
</tr>
<tr>
<td>12 months</td>
<td>11</td>
<td>(2-30)</td>
<td>(10)</td>
<td></td>
</tr>
<tr>
<td>Walking speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before treatment</td>
<td>1.1</td>
<td>(0.83-1.43)</td>
<td>(0.20)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>1.2</td>
<td>(0.83-1.66)</td>
<td>(0.23)</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>6 months</td>
<td>1.3</td>
<td>(0.1-1.66)</td>
<td>(0.23)</td>
<td>&lt;0.05b</td>
</tr>
<tr>
<td>12 months</td>
<td>1.3</td>
<td>(0.71-1.66)</td>
<td>(0.21)</td>
<td>&lt;0.01c</td>
</tr>
<tr>
<td>Walking 10 m with horizontal head movements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before treatment</td>
<td>1.0</td>
<td>(0.52-1.6)</td>
<td>(0.24)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>1.1</td>
<td>(0.71-1.43)</td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>1.2</td>
<td>(0.71-1.67)</td>
<td>(0.25)</td>
<td>&lt;0.01b</td>
</tr>
<tr>
<td>12 months</td>
<td>1.2</td>
<td>(0.71-1.66)</td>
<td>(0.23)</td>
<td>&lt;0.01c</td>
</tr>
<tr>
<td>Walking 10 m with vertical head movements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before treatment</td>
<td>1</td>
<td>(0.55-1.25)</td>
<td>(0.20)</td>
<td></td>
</tr>
<tr>
<td>1 month</td>
<td>1.2</td>
<td>(0.83-1.43)</td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>1.3</td>
<td>(0.71-1.67)</td>
<td>(0.16)</td>
<td>&lt;0.01b</td>
</tr>
<tr>
<td>12 months</td>
<td>1.2</td>
<td>(0.71-1.42)</td>
<td>(0.19)</td>
<td>&lt;0.0011</td>
</tr>
</tbody>
</table>

SREC, sharpened Romberg eyes closed; SOLEC, standing on one leg eyes closed. a The difference between before and after 1 month. b The difference between before and after 6 months. c The difference between before and after 12 months.
Dizziness, balance and rehabilitation... 

Figure 10. Difference between before and after 12 months in the length of steps during walking 10 m in normal speed and walking with the head moving horizontally/vertically (p<0.01**).

Figure 11. Vertigo during certain movements using VAS (mean value) was decreased 1, 6 and 12 months after treatment (♦)(p<0.001). Vertigo not associated with movement decreased 1 month (p<0.01) after treatment (■), but no further decrease after 6 and 12 months. Unsteadiness during standing and walking was decreased 1 month after treatment (▲)(p<0.01). There was no difference in terms of rotatory vertigo (●).
Study IV
The results from the questionnaires on dizziness and impaired balance are presented in Table 7. Thirty-six percent (242/675) experienced dizziness or impaired balance (sometimes or frequently). A significant gender difference was found. Twenty-eight percent felt unsteady when walking outdoors, more pronounced in women.

The results of the side-lying test are presented in Table 8. A positive side-lying test indicating BPPV was found in 11%. BPPV was significantly more common in women. A significant preponderance for right-sided BPPV was found and a bilateral positive side-lying test was found in 36%. Only 27% (17/63) with BPPV had consulted a doctor about dizziness symptoms.

The results of the clinical balance tests and questionnaire are presented in Table 9. Persons with BPPV displayed a significantly impaired ability to maintain balance in the sharpened Romberg with eyes open and standing on one leg with the eyes open compared to persons without BPPV. Persons with BPPV walked significantly more slowly and with shorter step lengths. Finally, subjects with BPPV reported significantly more subjective problems with dizziness and balance.
Table 7. Results from the questionnaire regarding dizziness with gender differences in percent.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Total</th>
<th>Women</th>
<th>Men</th>
<th>P-value for gender difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=675</td>
<td>n=398</td>
<td>n=277</td>
<td></td>
</tr>
<tr>
<td>Do you have any problems with dizziness or impaired balance?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>32</td>
<td>36</td>
<td>26</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Never</td>
<td>64</td>
<td>60</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Do you experience unsteadiness when walking outdoors?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>24</td>
<td>26</td>
<td>19</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Never</td>
<td>72</td>
<td>68</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Do you have problems with vertigo/dizziness when turning in bed, bending</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>15</td>
<td>17</td>
<td>12</td>
<td>ns</td>
</tr>
<tr>
<td>Never</td>
<td>84</td>
<td>82</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Do you experience vertigo when sitting or lying still?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>ns</td>
</tr>
<tr>
<td>Never</td>
<td>93</td>
<td>93</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>Do you experience constant vertigo/dizziness?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>ns</td>
</tr>
<tr>
<td>No</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Results from the questionnaire regarding dizziness with gender differences in percent.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Total</th>
<th>Women</th>
<th>Men</th>
<th>P-value for gender difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have any problems with dizziness or impaired balance?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently</td>
<td>4</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>32</td>
<td></td>
<td>36</td>
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<tr>
<td>Never</td>
<td>64</td>
<td></td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you experience unsteadiness when walking outdoors?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently</td>
<td>6</td>
<td></td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>24</td>
<td></td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>72</td>
<td></td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have problems with vertigo/dizziness when turning in bed, bending backwards/forwards?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequently</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>15</td>
<td></td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>84</td>
<td></td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you experience vertigo when sitting or lying still?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5</td>
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<tr>
<td>No</td>
<td>95</td>
<td></td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you experience constant vertigo/dizziness?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5</td>
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<tr>
<td>No</td>
<td>95</td>
<td></td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ns</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 8. Prevalence of Benign Paroxysmal Positional Vertigo (BPPV) with gender differences, affected ear and during side-lying test.

<table>
<thead>
<tr>
<th>Affected ear</th>
<th>Total</th>
<th>Women</th>
<th>Men</th>
<th>P-value</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BPPV</td>
<td>63 (11%)</td>
<td>46 (14%)</td>
<td>17 (7%)</td>
<td>&lt; 0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>25 (40%)</td>
<td></td>
<td></td>
<td>&lt; 0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>15 (24%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Mean value (SD) and significant differences in static and dynamic balance tests in people with and without BPPV.

<table>
<thead>
<tr>
<th>Variable</th>
<th>With BPPV</th>
<th>Without BPPV</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharpened Romberg with eyes open (s)</td>
<td>20 (10.6)</td>
<td>25 (8.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sharpened Romberg with eyes closed (s)</td>
<td>6 (7.8)</td>
<td>7 (7.6)</td>
<td>ns</td>
</tr>
<tr>
<td>Standing on one leg with eyes open (s)</td>
<td>14 (10.0)</td>
<td>18 (10.9)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Walking 10m without head movements (m/s)</td>
<td>1.10 (0.27)</td>
<td>1.18 (0.27)</td>
<td>ns</td>
</tr>
<tr>
<td>Length of step during 10 m walking (m/step)</td>
<td>0.60 (0.09)</td>
<td>0.64 (0.11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Walking 10m with horizontal head movements (m/s)</td>
<td>0.83 (0.22)</td>
<td>0.94 (0.24)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of step during 10m with horizontal head movements (m/step)</td>
<td>0.55 (0.08)</td>
<td>0.60 (0.12)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Discussion

Methodological considerations

The collection of data differs to some extent between the studies. We mainly choose to perform prospective studies as they are considered to have a higher value as evidence than retrospective observational studies. To have prospective and longitudinal clinical studies is always troublesome due to strict inclusion and exclusion criteria as well as drop outs. This often results in small clinical materials with problems of generalization. Our studies are as large as many others, and in study IV very large. To test and perform vestibular rehabilitation in patients requires high skills and experience. All subjects in studies I-III were assessed and trained by two of the authors (LK and BB). Both are physiotherapists with many years of experience by working with patients who have neurological disabilities. The testing in study IV was performed by trained and specially educated nurses. All test procedures in study IV were monitored by two of the authors (LK, CM). It can however not be ruled out that some test procedures in 571 subjects were not optimal.

The tests used and the vestibular rehabilitation performed all have strength and weaknesses. The assessment of nystagmus by the use of video-nystagmoscopy in study I is a very widespread clinical routine also used in many studies concerning dizziness and vertigo. This diagnostic test is however not quantitative but rather a visual subjective assessment of the existence of nystagmus. Caloric testing by the use of ENG have been in clinical routine for many years, but have in the last years been substituted with video-nystagmography. The use of pathological asymmetry of >20° is valid in most laboratories since 1956.

Questionnaires were used in all studies. At the time of the first studies, very few questionnaires existed if any with proven reliability and validity. Today (2011) the Dizziness handicap inventory is used in some reports. The DHI questionnaire includes 25 items concerning dizziness-associated disability and handicap. Three subscales are used, physical, emotional and functional scale. The test-retest reliability of the DHI has been determined as good. Another questionnaire, the Activities-Specific Balance Confidence scale (ABC) consist of 16 items that measure the confidence during different activities on a scale of 0-100%. The choice of questionnaire to use when treating patients with dizziness and unsteadiness is not obvious. DHI addresses the level of participation and the ABC addresses the level of activity, no single questionnaire is sufficient to cover
the entire dizziness-vertigo spectra. If the studies were performed today, we would probably have used some of these questionnaires. It is a weakness in our studies that we in some questionnaires lack reliability and validity. Furthermore, some of the questions were only answered yes or no, which makes it difficult to assess the severity of symptoms (headache, tinnitus etc). The questionnaires in our studies are study-specific for our purpose.

The purposes of study I and II were to explore the existence and severity of vertigo, unsteadiness, physical exercises and general health using VAS since this has been applied in many studies over time\(^77, 156\). In a study similar to study II, VAS was used to test-retest questions concerning dizziness which showed high ICC values between 0.85-0.96\(^74\). The results from the VAS in articles (I, II, III) are presented as mean and SD, but it would probably have been better to present data as median and interquartile\(^1\). However a new analysis revealed very small and not significant differences between median and mean values.

The static tests such as Romberg and standing on one leg have been used in many studies. These tests have shown good test-retest reliability in healthy subjects\(^14, 23, 159\) and in patients with dizziness\(^74\).

In study II we used a reference population with age and sex matched healthy volunteers. The reference group comprised different professionals. The same dynamic balance tests were used in Studies II, III and IV. Comfortable walking speed has shown to have high reliability \((r = 0.90)\) during a single test\(^15\), but walking with head movements has not yet been tested for reliability. We think it is important to perform complex clinical balance tests such as walking with head movements. We applied new tests that have not to our knowledge been reported before. Walking with head movements was performed both in patients (II, III, IV) and in a reference group (II). The walking test in elderly showed significant differences between subjects with and without BPPV, but validity and reliability is uncertainty since we have no results from other elderly populations. Counting number of steps is in many neurological departments routine but unfortunately there are to our knowledge no scientific reports. The height and body weight were not taken into account in studies II and III since Samson et al. found that stride length was not associated with age, height and body weight\(^128\).

The Dix-Hallpike test is clinical routine, with clear evidence of BPPV by assessment of nystagmus and vertigo. The side lying test has been evaluated by comparison with Dix-Hallpike. These studies are however quite small\(^27, 47\). The side lying results in our subjects could not be replicated by a Dix-Hallpike test due to the nature of the elderly population. The decision to use the Semont maneuver and not Epley, was made by reviewing previous
reports. Because of the limited studies with comparisons between the Semont and the Epley maneuver, no conclusion about differential effectiveness could be drawn. Based on our knowledge and clinical experience at that time, we chose Semont’s maneuver in Study III. The vestibular rehabilitation program used in study I and II was constructed by clinical experience from the dizzy clinic in Linköping, Sweden.

We missed a good measurement of compliance since we didn’t use exercise diary to find out how much the patients exercised at home.

In study IV participants were randomly selected from the population register. Some participants refused to participate, is a frequent problem in cross-sectional studies. Those that declined to participate may have been in poorer health, which makes it more difficult to generalize the results to the general population of elderly persons. There was also a discrepancy between those that only completed the questionnaire compared with those that also performed clinical tests (675/571). The reason for not participating in the test battery was predominantly due to immobility and tiredness.

General discussion

Study I
In Study I, 44 patients were originally included. Fifteen patients were excluded because they did not complete all tests and 2 patients were excluded due to brainstem tumours. Since 33/44 patients performed the second caloric assessment after six months (study II), we believe that the 15 patients who did not performed caloric’s, did not differ from the 27 patients in study I. A failure analysis was performed and showed no statistical difference.

All patients had undergone vestibular rehabilitation, started within 48 hours after onset. Corticosteroid therapy has been suggested to improve the recovery of peripheral vestibular function after AUVL. This was not used in our studies, as we believe that the main rehabilitative tool still is vestibular rehabilitation. Before the study started, a possibility of having a controlled randomized study with a control group without vestibular rehabilitation was discussed. This was abandoned, as we considered this unethical due to results from other studies and our own clinical experience of early vestibular rehabilitation.

Our study revealed that spontaneous nystagmus disappeared rapidly, which was not the case with head-shaking nystagmus. This indicates that the recovery was not complete and that it is not correct to only perform static nystagmus evaluation. This was further demonstrated by the fact that
none of the patients had spontaneous nystagmus after six months, while 54% of the patients displayed head-shaking nystagmus after one month and 19% after six months. We have not used a head-impulse test in our studies, since this was not in clinical use at that time. Kim et al. found a relationship between persistent dizziness, and a positive head-impulse test and vestibular asymmetry. Clinically compensated vestibular asymmetry can be found a long time after the debut, as has been shown by Möller et al., who demonstrated an asymmetric VOR gain in clinically compensated patients using high-frequency rotational tests. Spontaneous nystagmus represents a static position, indicating asymmetry between the vestibular organs and also a lack of central compensation of this asymmetry. Head shaking, on the other hand, represents a physiological dynamic movement, reflecting natural everyday activities. These early findings are therefore essential in order to understand the importance of head-shaking nystagmus as a tool to evaluate an ongoing habituation and change of plasticity. It is generally accepted that head-shaking nystagmus is generated by an asymmetrical peripheral vestibular input and a central velocity storage mechanism, indicating that a problem in the vestibular system exists or has existed. Some studies have found a significant relationship between caloric weakness and the occurrence of head-shaking nystagmus in patients with peripheral unilateral vestibular disease, but this was not the case in our study. The discrepancy we and others have found between caloric asymmetry and head-shaking nystagmus could depend on the fact that caloric asymmetry is not a physiological stimulus compared to natural head movements. Another difference is that caloric stimulation only produces low-frequency stimulation of the vestibular system. Comparisons of our results in the caloric tests with those of others are difficult to make, as the patients were examined at different times and sometimes using different techniques. However, the caloric asymmetry found after six months was similar to that reported by others. Our results showed that spontaneous nystagmus and caloric asymmetry do not always coincide. No significant correlation was found between the degree of asymmetry at onset and spontaneous nystagmus. Park et al. found nine patients with normal caloric reaction two months after AUVL onset and four of these nine patients had spontaneous nystagmus. It should also be noted that an acute vestibular loss can be caused primarily by lesions in the inferior vestibular nerve, with a normal caloric reaction. Although the examinations performed in this study were not aimed at the precise determination of the site of the lesion, these diagnostic procedures were conducted according to clinical routines and two of our patients were excluded due to skull-base tumours. After six months, only 4 patients
remained on sick leave. Interestingly, these four patients showed a higher caloric asymmetry compared to patients who were at work. One reason for this significant correlation may be that large caloric asymmetry reflects poor central compensation or ongoing vestibular deterioration. Large caloric asymmetry at disease onset and higher ratings of subjective symptoms can correlate at follow-up after 6 months. We also found that the degree of caloric asymmetry was positively related to the occurrence of spontaneous nystagmus and unsteadiness at follow-up. This has not been confirmed by others. The subjective vertigo was reduced rapidly during the first month. Unsteadiness when standing and walking and sick leave were positively correlated and an age correlation was found, with higher ratings of dizziness on the VAS at six months, which is in agreement with others. General unsteadiness is a common symptom and increases with increasing age. Together with other pre- or post-existing ailments, this may explain why older patients in our study had a higher degree of sick leave at six months. We therefore suggest that special attention should be paid to elderly people with AUVL and appropriate training should be given.

**Study II**

All 42 patients who had undergone vestibular rehabilitation six months prior, managed to perform the Romberg test with eyes closed for 60 seconds and SOLEO for 30 seconds. These tests are obviously too easy to be used in clinical assessment after AUVL. However, when using more difficult balance tests such as SREC and SOLEC, significant differences were found compared to the reference group. There was a definite visual dependence and different explanations are possible. Patients who have had AUVL with severe vertigo and vomiting for several days may have long-lasting fear and anxiety which may increase the contribution of visual sensory input to control balance. A recent study by Mbongo et al. found that patients with vestibular loss had greater lateral instability compared to a healthy reference group. This was observed in the acute stage and still existed after the 6-month follow-up. One explanation for this could be that asymmetric sensory information from the vestibular system, and somatosensory afferents in the feet and ankles plays an important role in determining the postural strategy.

The walking speed and length of the steps in the AUVL group showed a significant difference to the reference group despite the subjective self-assessments which revealed that 19/42 patients experienced minor problems with dynamic unsteadiness. The results from walking with the addition of head movements in order to mimic the natural walking pattern
revealed even greater differences between the AUVL and reference group. The speed and number of steps in our reference group is in agreement with other studies\textsuperscript{15, 151}. Rosenhall et al. found a significant decrease in the number of vestibular hair cells at 40-50 years of age\textsuperscript{126}. This decrease might require a larger contribution from proprioception and visual input. These inputs are obviously more disturbed while walking with simultaneous head movements. The distinct walking patterns of the AUVL group, with shorter steps and a slower speed, are very similar to those exhibited by elderly people with postural instability, which we found in Study IV and have been demonstrated by others as well\textsuperscript{100, 138}.

The low VAS score on questions concerning unsteadiness when walking might seem surprising, but one explanation could be that our patients have automatically reduced their speed and rapid head movements, in order to feel steady. As a result, they do not experience vertigo/unsteadiness during dynamic balance performances. In some cases, impaired central compensation may still exist, despite a decrease in spontaneous nystagmus and a subjective decrease in dizziness. The occurrence of nystagmus and simple questions relating to dizziness may not be sensitive enough to measure central compensation. However, static balance tests with closed eyes and minimized somatosensory input (one leg) appear to be sensitive and dynamic tests are even more sensitive.

Another interesting finding was that the AUVL group had a much higher intake of anti-hypertensive drugs (26\%) compared with the reference groups (2\%). To our knowledge, this study is the first to confirm a significantly higher prevalence of high blood pressure in subjects with AUVL compared with a reference group. Recently, a study by Lee and colleagues suggested that transient dizziness prior to AUVL might indicate a vertebral-basilar insufficiency\textsuperscript{94}. Further studies should therefore be considered.

**Study III**

In Study III, our patients were recruited from the otolaryngology/audiology departments at three hospitals in the western part of Sweden and the original purpose was to compare three different treatment modalities (Brandt and Daroff, Semont’s and Epley’s maneuvers). It was, however, difficult to recruit patients from the county hospitals. This somewhat limited the study and finally, 17 patients were consecutively recruited at the Department of Audiology at Sahlgrenska University Hospital, Gothenburg. The original aim to recruit a large number of patients was also not fulfilled since we in our inclusion criteria wanted patients with long-lasting, severe BPPV (>3 months). This was due to
previous reports of a high degree of spontaneous remission within 3 months\textsuperscript{58, 97}. In this study, we used no control group, since several studies have already shown significant improvement as a result of Brandt and Daroff exercises and Semont’s and Epley’s maneuvers\textsuperscript{16, 37, 135}. There was, however, a lack of studies with long-lasting follow-up of symptoms, nystagmus and dynamic balance. The underlying etiology was idiopathic in the vast majority of subjects (15/17), a finding that has been made by others\textsuperscript{10, 91}.

In our study, the latency of nystagmus showed a mean of 4 seconds, which was still the case at the end of the study in the three patients who still suffered from vertigo while on the other hand, the duration of nystagmus decreased significantly. The duration of nystagmus during Dix-Hallpike test is interesting. Recently, in a study by Imai et al., in 111 patients with posterior canal BPPV, it was found that only 8 subjects had a duration lasting more than 40 seconds\textsuperscript{64}. This was thought to be induced by cupulolithiasis. In our study, the duration of the nystagmus was 21 sec before treatment reduced to 13 sec in the 3 patients with a positive Dix-Hallpike test after 12 months. The reduced duration suggests that although some particles are left, the majority have been removed. There is also a possibility that debris in the canal decreases from a large mass to small free-floating otoconias.

The Dix-Hallpike test is a good test to verify BPPV, but it has been reported that patients can experience severe vertigo without any visible nystagmus\textsuperscript{55, 135}. In this study, only one patient experienced vertigo without nystagmus. This may be due to small free-floating debris rather than a larger mass\textsuperscript{55, 99, 155}. The elderly with positive side lying test in study IV showed in several cases vertigo without nystagmus indicating free floating debris. In Study III it was reported that the Dix-Hallpike test was performed before the examination of static and dynamic balance, which is incorrect, a mistake which unfortunately was printed. The correct order of performing tests is of importance since many patients experience unsteadiness during the first hours after a maneuver treatment\textsuperscript{10}.

The reason for choosing two Semont maneuvers before starting Brandt & Daroff exercises was based on findings in other studies\textsuperscript{10, 135}. In a study by Salvinelli et al., patients were randomized to the Semont maneuver, flunazine or no treatment. At the six-month follow-up, symptom resolution had occurred in 94\% of patients treated with the Semont maneuver compared to 38\% of patients medically treated\textsuperscript{127}. Soto Varela et al. randomized patients to treatment with the Epley, Semont maneuver or Brandt & Daroff exercises. Symptom resolution among those treated with either the Epley or the Semont maneuver was 74\%, whereas it was only
24% for Brandt & Daroff exercises\textsuperscript{145}. The Brandt & Daroff exercises were originally thought to enhance habituation and central compensation, but this might today be questioned, since it could simply be a “modified Semont maneuver” where subsequently the otoconias are moved out from the posterior canal. Eight patients in our study received additional Brandt & Daroff exercises. Of the total group, only three patients had BPPV symptoms after 12 months. Radtke et al. compared the efficacy of self-treatment using a modified Semont and Epley maneuver. Epley relieved 95% within 1 week, whereas the Semont maneuver relieved 58%. The failure of self-treatment with the modified Semont maneuver was probably related to incorrect maneuver execution with slow head and body movement\textsuperscript{123}.

The patients in our study followed given movement restrictions for 48 hours after the maneuver. The rationale for this was that the debris may move from the utricle into a new semicircular canal. However, a meta-analysis of six studies has recently found that restrictions after maneuvers are not needed\textsuperscript{39}.

The Romberg test was too easy with a ceiling effect. SREC and SOLEC are more difficult, but we found no significant improvement after treatment. In healthy individuals, aged 54 years, the mean SREC is reported to be 28 seconds\textsuperscript{159} and in our study, after 12 months, the mean SREC was 22 seconds which has to be considered pathological. In studies using computerized dynamic posturography the results improved after treatment, but the results were impaired compared to a control group\textsuperscript{13, 25, 30, 146}. Stamboliева et al. found that patients with BPPV less than 60 days after the first attack demonstrated a higher dependence on visual input for postural stability compared to patients who had a duration of more than 60 days\textsuperscript{146}. In our study, the inclusion criterion was symptoms lasting more than 60 days. Our results indicate that patients with BPPV have difficulty even with static balance compared to healthy individuals. This may be due to smaller yet persistent otolithic damage or maybe phobic postural instability which has developed secondary to the BPPV. The instability is seldom reported, since many reports concentrate on “curing” the vertigo. Further studies are needed in order to evaluate possible differences in stability, which also may depend on the etiology of BPPV. The walking tests improved significantly after treatment, especially the walking test with head movements. These tests are useful to perform and train as they provoke the vestibular system. It is important to use functional tests when evaluating dynamic balance and to practise head movements while walking.
The VAS revealed that patients with BPPV primarily experience dizziness and unsteadiness associated with certain movements and more rarely experience constant rotatory vertigo. The movement associated unsteadiness decreased after treatment but not entirely. To our knowledge, this has not been elucidated before. Ten out of 17 patients continued to have neck and shoulder pain even after the BPPV symptoms were resolved. By not moving the head because of long lasting fear of vertigo, tension in the neck may result in pain and increased efferent signals activating the appropriate postural muscles, which can lead to unsteadiness during standing and walking and dependence on vision to maintain balance.

### Study IV

The H 70 study is a unique population-based study of normative aging in 70-year-olds, which started in Gothenburg in 1971, focusing on both medical and cognitive dimensions. The dizziness and BPPV study was a part of the large H 70. Our study included persons 75 years of age, with a preponderance for women (59%), consistent with previous H 70 studies. There are some studies investigating the prevalence of dizziness in elderly persons. These studies have primarily used questionnaires. In this study, we wanted to explore an elderly population using different assessments such as questionnaire, BPPV tests, static and dynamic balance tests. Our study revealed that 36% of elderly persons had problems with dizziness or impaired balance which is in agreement with Jonsson et al., who found that 33% of 70-year-old subjects had dizziness or imbalance problems. We also found a high rate of unsteadiness while standing and walking outdoors (36%), which has been reported previously. Different causes of unsteadiness can be age-related changes due to reduced vestibular input or, as we suggest, partly by specific vestibular causes such as BPPV. A BPPV can be further aggravated by changes in calcium metabolism and microvascular ischemia. A general decline of the somatosensory and visual systems can also be associated with postural instability.

We choose to use a side-lying test instead of the Dix-Hallpike test, regarded to be the gold standard for diagnosing posterior semicircular BPPV. This test can however be difficult to perform in elderly persons because of their limited cervical range of motion. The side-lying test has been shown to be a good indicator of BPPV. There is a possibility that the side-lying test may underestimate the prevalence of BPPV, since it does not provide the full range of motion needed to provoke the movement of otoliths in the posterior semicircular canal. One possible weakness of our study is that we did not use video-nystagmoscopy during the side-lying test.
This was due to the large amount of subjects and time constraints. On the other hand, there is an ongoing discussion about the necessity to ensure detectable nystagmus by video-nystagmography during Dix-Hallpike testing\textsuperscript{55}. Our finding of BPPV in 11\% of subjects is slightly higher than that found by Oghalai, who reported a prevalence of 9\%\textsuperscript{115}. A retrospective study of 1194 patients over 70 years of age revealed that 19\% reported vertigo in conjunction with BPPV\textsuperscript{84}. We found a significant gender difference, where women had a significantly higher prevalence of BPPV. This female preponderance is still poorly understood, but one hypothesis could be a possible correlation between BPPV and osteoporosis. The loss of otolith function decreases linearly with age and at a greater rate in females compared with males. Some authors have suggested a possible correlation between the loss of otolith function and the risk of falls\textsuperscript{70,136,161}. Further prospective studies are needed to confirm these findings. One interesting and somewhat depressing finding was that only 27\% of elderly with BPPV had consulted a physician because of dizziness. One possible explanation could be that dizziness only occurs during certain movements and, by moving slowly and avoiding movements, dizziness occurs less frequently. Another explanation is that professionals (and patients) may interpret the symptoms as a normal feature of aging. Since BPPV can be treated and cured, we think it is important to make the public aware of our findings.

Our study showed a significant prevalence of right-sided BPPV. This is in accordance with others who also found preponderance in the right ear\textsuperscript{164}. A hypothesis could be that a majority has a preference for a right head-lying position on sleep onset\textsuperscript{92}. The causes might be due to an uncomfortable awareness of heartbeats when lying on the left side\textsuperscript{92,164}. At the time of our study, we were not aware of this hypothesis, whereas today we would have asked questions about sleeping habits. Symptoms of bilateral BPPV can be due to otoconia in the horizontal canal. But horizontal canal BPPV has often longer duration (>1 min) and a horizontal nystagmus and dizziness on both sides\textsuperscript{38}. In our study, the duration of vertigo had a mean of 14 seconds, which does not seem typical of horizontal canal BPPV. There are good reasons for further exploration of the prevalence and origin of bilateral BPPV. The elderly persons with BPPV received information about the disorder and were recommended to seek medical treatment in order to reduce symptoms of BPPV.

To maintain balance, collaboration is required between several complex systems and there are few standards for balance measures. In this study, we chose not to use the standard Romberg test, since we have found this test to be too easy to perform, with a ceiling effect even in the elderly. Our
elderly people with BPPV showed significantly more impaired static balance performance in the sharpened Romberg test compared to elderly persons without BPPV. There may be many reasons for this postural instability. One possible explanation could be a sensory conflict in the vestibular system due to asymmetric vestibular input caused by loose otoconias and subjects with BPPV have been shown to be more visually dependent than healthy adults\textsuperscript{13, 30, 146}. A combination of BPPV, sensory decline and cognitive deficits may further enhance balance problems in subjects with BPPV.

In the walking test without head movements, we found no differences between elderly with and without BPPV, but walking with head movements revealed highly significant differences. The reasons could be the same as discussed above and additionally could the head movements disperse otoconia into the semicircular canals, which might result in imbalance. Our study demonstrated that elderly people in general and especially elderly people with BPPV have a short length of steps and slow walking. It has been reported that a shorter length of steps and slower walking are related to fear of falling\textsuperscript{100}. Untreated and treated BPPV will probably still result in abnormal walking patterns which also was demonstrated in study III. This can create general instability, fear of falling, subsequent falls and possible fractures. Teggi et al. demonstrated that patients with BPPV and a long duration of symptoms before diagnosis had higher anxiety level, which was found especially in elderly\textsuperscript{153}.

**Conclusions and future research**

These thesis have investigated two common vestibular disorders where we have focused on AUVL and BPPV at different ages and with a long time follow up. The conclusions drawn are that AUVL is a disorder which has a good prognosis concerning disappearance of rotatory vertigo. The long term effects shows an increased static and dynamic instability which can be correlated with subjective feelings of unsteadiness. The AUVL patients were significantly more visually dependent and walked more slowly compared to the reference group. In BPPV, the treatment with Semont’s manoeuver showed very good results in eradication of rotatory vertigo, but as in the patients with AUVL, the long term follow up displayed impaired balance. The high prevalence of dizziness and BPPV in a very large cohort of elderly was surprising. These findings indicate that vertigo when changing position is not only due to cardio-vascular abnormalities, but also BPPV which can and should be examined and treated. There is moderate to strong evidence that vestibular rehabilitation is effective for patients with peripheral vestibular dysfunction, and the vestibular rehabilitation should
be intense and start very soon after diagnosis\textsuperscript{51, 59}. To use resources efficiently we need to identify the patients who are a risk of poor outcome and motivate patients to undertake vestibular rehabilitation. The most important goal for vestibular rehabilitation is to help patients with AUVL to rely as much as possible on their remaining vestibular function. We used the same dynamic balance tests in study II, III and IV and the use of these dynamic tests is important since they are difficult enough to avoid ceiling effects, and are suitable for training purposes as well. One way for the patient to get back into normal gait pattern is to show the difference between short and long strides, and encourage an increase of length of steps. Future research should focus on better vestibular rehabilitation procedures, validated tests and to explore possible correlations between vestibular disorders anxiety, cognitive function, vestibular disorders and balance.
Svensk sammanfattning

Yrsel, balans och rehabilitering vid balanssjukdomar i innerört

För att människan skall upprätthålla en god balansfunktion krävs ett samarbete mellan olika sensoriska organ såsom syn, innerörats balansorgan, muskel, led och hudkänsla samt bearbetning av dessa signaler i centrala nervsystemet. Information från de sensoriska organen som inte stämmer överens (sensorisk konflikt), kan ge upphov till yrsel. Ostadighet och yrsel är vanliga symtom beroende på olika skador och sjukdomar. Yrsel och balansproblem är vanligt förekommande i högre åldrar.

Avhandlingen fokuserar på två av de vanligaste yrseldiagnoserna; godartad lägesyrsel (benign paroxysmal positionell vertigo, BPPV) och akut unilateralt vestibulärt bortfall (AUVL, vestibularisneuronit, balansnervsinflammation).

Studie I

Syftet var att beskriva effekten av vestibulär (balans) rehabilitering efter genomgången AUVL genom att registrera närvaro och sambandet mellan spontan- och huvudskaknings nystagmus, kalorisk asymmetri, subjektiv yrselupplevelse, ålder och sjuksskrivning. Ett annat syfte var att undersöka om nystagmus, kalorisk retbarhet, och subjektiva yrselsymptom vid insjuknandet kunde förutsäga återgång till arbete.

Metod: Tjugosjupatienter (51år) deltog i studien och instruerades i vestibulär rehabilitering som startade inom 48 timmar. Tillfrisknande mättes genom undersökning av spontannystagmus, huvudskakningsnystagmus och kaloriska tester. Frågeformulär avseende sjukskrivningsgrad och olika typer av yrsel, med en visuell analog skala (VAS), användes. Undersökningar gjordes vid fyra tillfällen. (insjuknande, akutstadiet, 1 mån, 6 mån)


Studie II

Syftet var att utvärdera statisk, dynamisk balans och hälsa efter genomgången AUVL (6mån).

Resultat: AUVL gruppen var signifikant sämre i såväl statiska som dynamiska balanstester. Signifikant fler i AUVL gruppen använde blodtryckssänkande medicin.

Studie III
Syftet var att utvärdera långtidseffekten (12 mån) av utförda Semont’s manövrar och/ eller Brandt-Daroff träning hos patienter med långvarig BPPV (>3mån).

Studie IV
Syften var att undersöka prevalens av yrsel, ostadighet och BPPV hos äldre (75 år), och att jämföra statisk och dynamisk balans mellan de med och utan BPPV.
Metod: Sexhundrasjuttiofem personer svarade på frågor om yrsel och 571 personer utförde sidliggande test för BPPV samt statiska och dynamiska balanstester.
Resultat: Yrsel och ostadighet rapporterades av 36 %, fler kvinnor (40 %) jämfört med män (30 %). Vid sidliggande test befanns 11 % ha BPPV, och det var vanligare hos kvinnor jämfört med män. Personer med BPPV var signifikant sämre i statiska och dynamiska tester och hade signifikant mer yrsel och balansproblem jämfört med personer utan BPPV.

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