EEVA TUUNAINEN

Presbyequilibrium and Falls among Institutionally Residing and Community-Dwelling Older Adults

Characterization and prevention

A clinical study
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ACADEMIC DISSERTATION
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UNIVERSITY OF TAMPERE
EEVA TUUNAINEN

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ABSTRACT

As the population gets older, the need to manage dizziness/vertigo-related symptoms becomes more essential in everyday clinical work. The characterization of these symptoms in older adults is considered as a challenging and often frustrating experience for the physician due to its multi-faceted etiology and multi-symptomatic appearance. We evaluated the symptoms of vertigo/dizziness and balance problems among two groups of older adults; those residing in an institutional setting and those living actively in a community.

Vertigo/dizziness and balance problems were observed in 68% (49/72) of the older adults residing in institutional settings and in 44% (42/96) of those living in the community. Among institutionally residing older adults, frailty (r = 0.31, p = 0.010) and autonomic vertigo (r = 0.25, p = 0.041) were associated with falls, whereas in the community-dwelling older adults vestibular irritability (OR (Odds Ratio) = 1.8, p = 0.002), movement intolerance (OR = 1.8, p = 0.002) and autonomic vertigo/near syncope (OR = 1.5, p = 0.002) were associated with falls.

In posturography measurements among the community-dwelling older adults, fallers could be distinguished from non-fallers in the critical time for control of the open versus closed loop (t = 2.32 p < 0.02) and the zero crossing velocity (t = 2.00, p = 0.05). Institutionally residing older adults improved their postural stability measured in posturography after three months of muscle and balance training (p < 0.001).

In a fall prevention intervention we showed that with guided balance and muscle training institutionally residing older adults tended to reduce their number of falls when compared to self-administered training (p = 0.02). However, after the training had ended, the quality of life instrument showed reduced scores.

In the majority of the institutionally residing older adults who were studied, previously undiagnosed vestibular abnormalities such as reduced vestibulo-ocular reflex (VOR) gain, pathological head thrust test, spontaneous nystagmus, gaze evoked and/or positional nystagmus were found.

Presbyequilibrium encompasses the multi-symptomatic and multi-etiologic vertigo/dizziness and balance problems among the older adults. With factor analysis we could distinguish diagnostic and therapeutically meaningful presbyequilibrium groups among institutionally residing and community-dwelling older adults. In practice, collaborative presbyequilibrium clinics could help detect those older adults with a higher risk of falling and direct them to proper rehabilitation services.
Väestön vanhenemisen myötä ikääntyneiden huimauksen diagnoosinnin ja hoidon tarve sekä vaatimukset nousevat. Ikäään huimauspotilaan tutkiminen on usein haastavaa ja aikaa vievää useiden mahdollisten taustatekijöiden ja myötyvaikutusten vuoksi. Ikääntymiseen liittyvään huimaukseen ja tasapainon heikkenemiseen eli ikähuimaukseen vaikuttavat niin sisäiset henkilöstöjä johtuvat tekijät kuin ulkoisetkin tekijät, jotka tulee ottaa laajasti huomioon potilaan kokonaistilannetta arvioidessa. Ikähuimausta arvioitiin sekä laitoksissa asuvilta että kotona asuvilta aktiivisilta eläkeläisiltä.

Tutkimuksessamme ikähuimausta todettiin 68 %:lla (49/72) laitoksessa asuvista ikäästä ja 44 %:lla (42/96) kotona asuvista eläkeläisistä. Lihasheikkous (r = 0.31, p = 0.010) ja autonominen huimaus (r = 0.25, p = 0.041) ennakoivat kaatumista laitoksissa asuvilla, kun taas kotona asuvilla eläkeläissä sisäkorvaperäinen huimaus (OR = 1.8, p = 0.002), liikkumisen epävarmuus (OR = 1.8, p = 0.002) ja autonominen huimaus ennakoivat kaatumista (OR = 1.5, p = 0.002).

Kotona asuvien eläkeläisten kaatumistaipumus tuli esille tasapainolevyyllä suoritettavissa mittauksissa, jossa ne, jotka olivat kaatuneet, pystyttiin erottamaan joukosta kahden tasapainolevymuuttujan avulla (zero crossing velocity, critical time for control of the open versus closed loop). Laitoksissa asuvien ikääiden tasapainotuloksset paranivat kolmen kuukauden tasapaino- ja lihasharjoittelun jälkeen (p < 0.001).

Kolmen kuukauden ohjattu lihas- ja tasapainoharjoittelu vähensi kaatumisia laitoksissa asuvilla ikääkillä enemmän kuin omatoiminen harjoittelu (p = 0.02).

Kliinisissä sisäkorvatutkimuksissa suurimmalla osalla laitoksessa asuvilla ikääkillä oli sisäkorvasairaudesta kertovia testilöydettyjä, kuten asentohuimausta, tasapainoelin-silmä-refleksin heikentynyttä toimintaa ja silmävärvettä.

Ikähuimauksen terminä sisältää ikäään kokeman huimauksen ja tasapainohäiriöt, jotka voivat olla hyvin monimuotoiset. Faktorianalyysillä pystymme erottamaan diagnoositesti-ja hoidollisesti merkittäviä ikääken huimauksryhmiä, sekä laitoksessa että itsenäisesti asuvilla ikääkillä. Ikäään huimauksen monimuotoisuuden vuoksi moniammatillinen lähestyminen oireisiin ohjaa oikeaan diagnoosiin, tunnistaa suuremmassa kaatumisaarassa olevat ikääät ja varmistaa kohdettuihin jatkotutkimuksiin/hoitoon ohjautumisen.
This thesis is based on the following original publications:


<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCS</td>
<td>Activities Balance Confidence Scale</td>
</tr>
<tr>
<td>ADL</td>
<td>Activities of daily living</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis on Variance</td>
</tr>
<tr>
<td>BPPV</td>
<td>Benign Paroxysmal Positional Vertigo</td>
</tr>
<tr>
<td>CGA</td>
<td>Comprehensive Geriatric Assessment</td>
</tr>
<tr>
<td>CNS</td>
<td>Central Nervous System</td>
</tr>
<tr>
<td>COP</td>
<td>Center of Pressure</td>
</tr>
<tr>
<td>ENT</td>
<td>Ear, nose, and throat (Physician)</td>
</tr>
<tr>
<td>EQ-5D</td>
<td>5D Quality of Life Questionnaire</td>
</tr>
<tr>
<td>FES-I</td>
<td>Falls Efficacy Scale International</td>
</tr>
<tr>
<td>HRQoL</td>
<td>Health Related Quality of Life</td>
</tr>
<tr>
<td>HSN</td>
<td>Head-Shaking Nystagmus</td>
</tr>
<tr>
<td>ICD</td>
<td>International Classification of Diseases</td>
</tr>
<tr>
<td>LED</td>
<td>light-emitting diode</td>
</tr>
<tr>
<td>MCI</td>
<td>Mild Cognitive Impairment</td>
</tr>
<tr>
<td>ML</td>
<td>Medio-Lateral</td>
</tr>
<tr>
<td>MMSE</td>
<td>Mini Mental State Examination</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
</tr>
<tr>
<td>NCS</td>
<td>Neurocardiogenic Syndrome</td>
</tr>
<tr>
<td>OH</td>
<td>Orthostatic Hypotension</td>
</tr>
<tr>
<td>OR</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td>ProFaNE</td>
<td>Prevention of Falls Network Europe</td>
</tr>
<tr>
<td>QALY</td>
<td>Quality-adjusted life years</td>
</tr>
<tr>
<td>QoL-15D</td>
<td>15D Quality of Life Questionnaire</td>
</tr>
<tr>
<td>TTO</td>
<td>Time Trade Off Instrument</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual-Analogue Scale</td>
</tr>
<tr>
<td>VOG</td>
<td>Video-Oculography</td>
</tr>
<tr>
<td>VOR</td>
<td>Vestibulo-Ocular Reflex</td>
</tr>
<tr>
<td>VVOR</td>
<td>Vestibule-Visual Interaction</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Vertigo and dizziness among older adults are common complaints that have been reported among 30% of older adults over 65 years of age (Colledge et al., 1994, II) and increasing to 50% among older adults over 85 years of age (Jönsson et al., 2004). In addition, dizziness and vertigo in the older adults lead to fear of falling and a reduction of physical strength and mental health (Burker et al., 1995). In various population-based studies, dizziness has been regarded as a significant predictor for falls (Pluijm et al., 2006; Gassmann et al., 2009). Accidental falls are one of the leading causes of death among the older population. Additionally, fatal fall rates increase exponentially with age and are highest at the age of 85 years and over (WHO Global Report on Falls Prevention in Older Age, 2007).

The evaluation of dizziness in older adults is often a frustrating experience for physicians due to the difficulties in sorting through the multiple symptoms older patients often possess, a shortage of suitable physical examination findings or diagnostic tests for balance disorders and the wide range of potential causes for balance disorders. Older adults understand and describe their dizziness in many ways (Jönsson et al., 2004) and often tend to under-report their symptoms (Oghalai et al., 2000). In trying to understand what patients mean with the words “dizziness” or “vertigo”, doctors usually use several words to attempt to better define the nature of the disorder with terms such as "balance problems", "fear of falling", "feeling of floating", "light-headedness", "black-outs", "sudden instabilities", "falls" or "spinning of the environment".

In a retrospective chart audit study by Kwong and Pimlott (2005), a significant proportion of the older adults who came to primary consultation with vertigo were either diagnosed improperly or were considered to be simply symptomatic of their natural aging process. In another study, a significant proportion of patients with Benign Paroxysmal Positional Vertigo (BPPV) were referred to a Fall and Syncope Unit instead of to ear, nose and throat specialist (ENT) (Lawson et al., 2005). Diagnosing vestibular malfunction and vestibular symptoms in the older adults may be difficult, particularly as the symptoms are frequently reported as more than one type of dizziness, sometimes including vertigo, postural dizziness and symptoms from multiple comorbidities and coexisting cardiovascular disorders.
As there will understandably be a degree of unreliability in the reporting of vertigo/dizziness complaints among the older adults, efforts have been made to improve vestibular testing to assist the diagnostic process. However, there are only limited data on vestibular findings in the older adults (Baloh, 1992) and it is especially noted that there are little reports of such findings in the oldest age category.

Kerber et al., (1998) demonstrated an association of poor balance and accidental falls with the outcomes of postural and gait measurements. They regarded postural imbalance as a key factor for explaining accidental falls. Posturography is a common tool and has been widely used to test the postural stability in the older adults. Era et al., (2006) showed in posturography studies that the balance functions start to decline from relatively young ages and accelerates from 60 years upwards. Rasku et al., (2012, II) demonstrated that the decline of the postural stability continued to deteriorate up to 90 years of age, and by careful evaluation of a stabilogram the age of the subjects could be predicted by the outcome of the posturography with an accuracy of 5 years. However, the use of the standard force platform technique (with or without postural perturbation) has not improved the accuracy of prediction of a fall (Kingma et al., 2011). As such, a more sophisticated analysis of posturography might help to understand the mechanisms that lead to and predict falls.

The purpose in this study was to evaluate the characteristics of vertigo/dizziness and balance problems among two groups of older adults; those residing in an institutional setting and those living actively in the community. The complaint history and symptoms were queried using a structured otoneurological questionnaire. The vestibular symptoms were studied with neuro-otological examinations and postural performance was studied using posturography. The association between falls and complaints were explored. The study also aimed to explore whether physical exercise could improve postural stability and reduce falls.
2 LITERATURE REVIEW

2.1 Dizziness, vertigo and balance problems in the older adults

2.1.1 Complaint prevalence of dizziness, vertigo and balance problems

Vertigo and dizziness among older adults are common complaints that have been reported among 30 % of older adults over 65 years of age (Colledge et al., 1994, II). A lifetime prevalence of dizziness was 29 % of older adults over 60 years of age in a study presented by Sloane et al., (1989, I). However the terms “dizziness” and “vertigo” are usually poorly documented in most reports and may lead to variability in prevalence as observed in different studies.

Grimby and Rosenhall (1995) studied 565 community-dwelling older adults aged 76 years where one third of the group reported dizziness. They showed that dizziness had a significant influence on reducing the general health-related quality of life.

Jönsson et al., (2004) studied 2011 older adults between 70–90 years of age. The prevalence of balance problems (vertigo, dizziness and dysequilibrium) at the age of 70 years was 36 % and rose up to 51 % at the age of 90. Balance symptoms were more common among women than men. Daily occurrence of vertigo was 4 % at the age of 70 years and increased to 25 % at the age of 90 years.

Maarsingh et al., (2010, I) studied the prevalence and incidence of dizziness among 50601 older adults visiting family practice. The one-year prevalence of dizziness in patients aged 65 years or older was 8.3 %. Prevalence increased with age, from 6.7 % in the age group of 65–74 year-olds to 10.8 % in patients aged 85 years or older. During the registration year the incidence of dizziness was 47.1 per 1000 person years. For 39 % of the dizzy patients the family physicians did not specify a diagnosis.

Aggarwal et al., (2000) studied the prevalence of dizziness among biracial community population over 65 years of age. From 729 subjects the prevalence of dizziness was 9.6 %. It increased with age, from 6.6 % in those 65–74 years old, to 11.6 % in those 75–84 years old, and to 18.4 % in those persons of 85 years or older. It was more common in women than in men and did not associate with race.

In a study by Tinetti et al., (2000), 24 % of 1087 community-living older adults ≥72 years of age reported dizziness. Fifty-six percent of the dizzy persons described several sensations and 74 % reported several triggering activities.

The prevalence and criteria for dizziness in these studies are summarized in Table 1.
<table>
<thead>
<tr>
<th>Author</th>
<th>n</th>
<th>Inclusion age (years)</th>
<th>Time frame</th>
<th>Prevalence of dizziness (%)</th>
<th>Criteria for dizziness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggarwal et al., (2000)</td>
<td>729</td>
<td>&gt; 65</td>
<td>Lifetime</td>
<td>6.6–18.4 %</td>
<td>All participants were asked whether they had ever been dizzy or lightheaded (Yes/No).</td>
</tr>
<tr>
<td>Colledge et al., (1994)</td>
<td>900</td>
<td>&gt; 65</td>
<td>Lifetime</td>
<td>30.0 %</td>
<td>Dizziness was explored with a yes/no question. If the subject reported dizziness, t asked to complete a further eight questions regarding its characteristics.</td>
</tr>
<tr>
<td>Gomez et al., (2011)</td>
<td>1692</td>
<td>&gt; 60</td>
<td>1 month</td>
<td>15.2 %</td>
<td>Self-reporting of dizziness as a symptom experienced either very frequently or continuously during the last month.</td>
</tr>
<tr>
<td>Grimby et al., Rosenhall (1995)</td>
<td>565</td>
<td>76</td>
<td>Lifetime</td>
<td>29.0 %</td>
<td>The subjects recorded to have dizziness when answering affirmatively to ‘Are you bothered by dizziness, bad balance, or general unsteadiness?’</td>
</tr>
<tr>
<td>Jönsson et al., (2004)</td>
<td>2011</td>
<td>&gt; 70</td>
<td>Lifetime</td>
<td>36–51 %</td>
<td>Question: Are you troubled by vertigo, dizziness, disturbed balance or general unsteadiness? (Yes/No)</td>
</tr>
<tr>
<td>Maarsingh et al., (2010)</td>
<td>50601</td>
<td>&gt; 65</td>
<td>One year</td>
<td>6.8–10.1 %</td>
<td>Database search strategy with diagnosis or symptoms including the words dizziness, vertigo, fainting, syncope.</td>
</tr>
<tr>
<td>Pluijm et al., (2006)</td>
<td>1362</td>
<td>55–85</td>
<td>Three years</td>
<td>14.7 %</td>
<td>Dizziness was assessed by asking whether the respondent was dizzy on a regular basis (Yes/No).</td>
</tr>
<tr>
<td>Sloane et al., (1989)</td>
<td>1622</td>
<td>&gt; 60</td>
<td>Lifetime</td>
<td>29.3 %</td>
<td>Dizziness was severe enough to see a physician, to take medication or to interfere with daily activities.</td>
</tr>
<tr>
<td>Tinetti et al., (2000)</td>
<td>1087</td>
<td>&gt; 72</td>
<td>One month</td>
<td>24.0 %</td>
<td>Episodes of dizziness that were present for at least one month</td>
</tr>
</tbody>
</table>
2.1.2   Examinations of dizziness, vertigo and balance problems

Complaint history of dizziness, vertigo and balance problems among older adults

In a study by Jönsson et al., (2004) it was shown that older adults describe their symptoms in various, non-uniform ways. Some report true vertigo, a hallucination of motion that is most commonly represented as a distinct sensation of rotation or rocking. Others describe their dizziness as a sensation of unsteadiness, imbalance, disequilibrium and a feeling of unreality. Orthostatic obscuration of vision and even loss of consciousness are also reported.

An otoneurological questionnaire has been developed for assessing a thorough patient history for a patient with dizziness and/or balance problems. It is a standardized questionnaire with various questions about the subject’s medical history, medications, symptoms of vertigo or dizziness and balance problems (Kentala et al., 1996; 1999; 2000). It can be used when interviewing older adults and when necessary, interviews can be confirmed or augmented by the patients’ personal nurses.

Neuro-otological examinations

To assess the diagnosis of dizziness in the older adults, the same clinical tests can be used as those applied to younger patients. Basic tests include testing cranial nerves, Romberg’s test (Romberg, 1853), finger-to-nose test, diadochokinesis, Unterberger’s test (Unterberger, 1938) saccades and smooth pursuit-test. Vestibular testing starts with testing of nystagmus (spontaneous and induced including the Dix-Hallpike test) (Dix and Hallpike, 1952), head thrust tests and VOR-tests (vestibulo-ocular reflex) (Brandt and Strupp, 2005).

Gaze stabilization and eye-head coordination

Testing the vestibulo-ocular system includes inspecting ocular alignment, smooth-pursuit and saccadic eye movements with the head fixed, and head movement (vertical and horizontal) with the eyes fixed on a stationary point (the test for VOR function or gaze stability) or fixed on a moving target (the test for VOR cancellation) (Brandt and Strupp, 2005). Smooth pursuit eye movements are tested by asking the patient to follow a moving target in all directions while keeping the head stable. Saccadic eye movements are tested by asking the patient to look back and forth quickly between two targets placed vertically and horizontally. VOR can be tested by asking the patient
to read a visual acuity wall chart with the head stationary and then to read the chart again when the head is either actively or passively rotated side to side at a frequency of 2 Hz. Another method of examining gaze stability is to perform rapid head thrusts.

Positional provocation testing

Positional provocation testing involves having the patient move quickly in various daily life normal movements which are assumed to provoke dizziness (Table 2). A common positional test used to diagnose BPPV is the Dix-Hallpike maneuver (Dix and Hallpike, 1952; Brandt and Strupp, 2005) to test posterior and anterior semicircular canals. To perform this test, the patient is positioned sitting on an examination table with the head rotated 45 degrees toward one side; then the subject is moved from the sitting position into a supine position with the head hanging back over the edge of the table with approximately 30 degrees of neck extension. Horizontal semicircular canals are tested with the patient in supine position rotating head 45 degrees to each side. The posterior semicircular canal is the most common site of dysfunction, although other semicircular canals may alternately be involved. This can be diagnosed with an appropriate positioning test and by observation of the direction of the nystagmus. Signs for nystagmus and subjective symptoms are observed and torsional nystagmus with the eyes beating toward the affected side and forehead (up) is observed with posterior canal BPPV.

There are rather limited data on vestibular findings in the older adults and especially amongst the oldest age group. Imbaud-Genieys (2007) studied 100 patients over the age of 75 years and found BPPV among 68% of the cohort, Menière’s disease among 5% and vestibular areflexia in 4%. It was conducted that the diagnosis of BPPV in the older adults is challenging because the vertigo symptoms don’t appear the same way as seen in the younger population. Therefore testing of vertigo/dizziness in the older adults is challenging and should be explored with a complete vestibular examination. In a study by Colledge et al., (1994, II) with 900 older adults aged over 65 years, it was reported that 30% had dizziness most commonly provoked by postural change and head movement.
Table 2. Neuro-ophthalmological and neuro-otological examinations for a dizzy patient

<table>
<thead>
<tr>
<th>Type of examination</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes position/movement (with/without Frenzel’s glasses)</td>
<td>Spontaneous nystagmus</td>
</tr>
<tr>
<td>Lateral gaze (20–30 degrees)</td>
<td>Gaze evoked nystagmus</td>
</tr>
<tr>
<td>Smooth pursuits</td>
<td>Eye movement smooth or saccadic</td>
</tr>
<tr>
<td>Saccades</td>
<td>Eye movement; velocity, accuracy.</td>
</tr>
<tr>
<td>Head-shaking test (with Frenzel’s glasses)</td>
<td>Provoked nystagmus</td>
</tr>
<tr>
<td>Head thrust test</td>
<td>Re-fixation saccades</td>
</tr>
<tr>
<td>Dix-Hallpike test</td>
<td>Nystagmus findings</td>
</tr>
<tr>
<td></td>
<td>(torsional, upbeating, downbeating)</td>
</tr>
<tr>
<td>Romberg’s test</td>
<td>Standing instability</td>
</tr>
</tbody>
</table>

2.1.3 Underlying comorbidities for dizziness, vertigo and balance problems

It is widely presented that dizziness, vertigo and balance problems in the older adults are multi-symptomatic and multi-etiologic. Colledge et al., (1996) studied the causes of dizziness among 149 older adults suffering dizziness. The most common diagnoses were central vascular disease and cervical spondylosis, often accompanied by poor vision and anxiety. Sloane et al., (1989, I) presented neurosensory deficits, a cardiovascular risk score and depression as being the strongest variables displayed with dizziness in the older population.

Neurocardiogenic syndrome (NCS) and orthostatic hypotension (OH)

Neurocardiogenic syndrome is defined as a syndrome in which “triggering of a neural reflex results in a usually self-limited episode of systemic hypotension characterized by both bradycardia (asystole or relative bradycardia) and peripheral vasodilation” (Benditt et al., 1996). Hypovolemia and other conditions reducing cardiac preload can induce NCS. Rafanelli et al., (2014) studied 873 syncope patients (aged 66.5 ± 18 years) with tilt testing, carotid sinus massage and both supine and upright blood pressure measurements. Tilt testing was diagnostic in 50.4 % of the cases, carotid sinus massage was diagnostic in 11.8 % of the cases and OH was present in 19.9 % of the cases. Patients over 65 years of age had a higher rate of complex diagnoses. Identification of NCS in patients with hypersensitive cardio-inhibitory reflex is important,
as Crilley et al., (1997) demonstrated that with the insertion of a pacemaker for these patients falls can be prevented.

Orthostatic hypotension is common in the older adults and its prevalence increases with age and often signals subliminal autonomic neuropathy (Kenny 2002, 2003). A significant proportion is associated with cardiovascular disease, such as sick sinus syndrome. Maarsingh et al., (2010, II) studied 417 older adults with persistent dizziness. They concluded that in 57 % of the study group, the cardiovascular diseases were the main contributor to dizziness, followed by peripheral vestibular disease (14 %) and psychiatric illness (10 %). An adverse drug effect was considered to be the most common minor contributory cause of dizziness (23 %). Jäntti et al., (1993) concluded that both postural and chronic hypotension are associated with falling among older adults living in an institution. A drop in the systolic blood pressure after standing up or chronic hypotension did not cause any symptoms like dizziness and a fall might therefore be a direct result of the hypotension.

Frailty

Fried et al., (2001) studied 5317 community-dwelling older adults over 65 years of age with annual interviews and examinations to define frailty. They evaluated outcomes including hospitalization, incident diseases, falls, disability and mortality. They defined frailty as a clinical syndrome if three or more of the following criterion were present: unintentional weight loss (4.5 kg in past year), self-reported exhaustion, weakness (grip strength), slow walking speed, and low physical activity. The prevalence of frailty was 6.9 % and the four-year incidence was 7.2 %. Prevalence increased with age and was greater in women than men. In our study frailty is considered as a combination of symptoms that include widely same features as the frailty syndrome.

In a study by Lipsitz et al., (1991) among institutionally residing frail oldest adults (mean age 87 years), 26 % of recurrent fallers had multiple conditions that could not be directly pinpointed as the reason for fall. Fallers were more often women, were functionally impaired and were taking more medications than non-fallers, although specific diseases did not distinguish fallers from non-fallers. Fallers took more steps to turn 360 degrees, could not stand up from a chair without pushing off with the help of hands, had a higher prevalence of antidepressant use and had an impaired position sensation.

Ensrud et al., (2007) studied 6724 frail women ≥ 69 years of age and followed them prospectively regarding incident falls, fractures, and mortality. They subsequently ascertained that frail women were at an increased risk of recurrent falls, hip fracture,
any non-spine fracture and death. The associations between frailty and these outcomes persisted among women ≥ 80 years.

**Visual impairment**

Visual impairment among the older adults causes balance problems, dizziness and can lead to falls. Maarsingh et al., (2014) identified predictors for regular dizziness among 1379 older adults (≥ 60 years of age). They concluded that predictors of regular dizziness at a seven-year follow-up were living alone, history of dizziness, history of osteo/rheumatoid arthritis, use of nitrates, presence of anxiety or depression, impaired vision and impaired function of lower extremities.

Lee and Scudds (2003) conducted a cross-sectional study to compare the balance ability of older adults (≥ 65 years of age) with and without visual impairment. Balance was measured using the Berg balance scale. They concluded that balance was more impaired with greater visual impairment.

Aartolahti et al., (2013) studied 576 community-dwelling older adults (aged 76–100) using a seven-item functional vision questionnaire and the Berg balance scale, timed up and go test, chair stand test and maximal walking speed test. In the analysis, participants were classified into poor, moderate or good functional vision group. Participants with poor functional vision performed worse on all balance and mobility tests. They concluded that poor functional vision is related to weaker balance and mobility performance in the community-dwelling older adults.

**Inner ear changes**

In addition to age-related degenerative processes in the vestibular system (Rosenhall and Rubin, 1975), the older adults may suffer from inner ear disorders such as Menière’s disease and BPPV.

In a cross-sectional study by Oghalai et al., (2000), unrecognized BPPV was found in 9 % of older adults. Subjects were community-dwelling and did not have a previous diagnosis of BPPV. Patients with unrecognized BPPV were more likely to have reduced activities of daily living (ADL) scores, to have sustained a fall in the previous three months and to have depression.

In a study of patients with dizziness aged 70 years or older, Bloom and Katsarkas (1989) found 40 % (328/806) having BPPV. In an additional study, Katsarkas (1994) studied 1194 older adults who were 70 years of age or older in a dizziness clinic. In 530 cases (39.1 %), BPPV was diagnosed. The author concluded that syndromes
affecting vestibular function may be more prevalent in advanced age than is generally estimated.

Central pathologies

The need for proper methods to differentiate possible central lesions from peripheral causes of dizziness is undisputed. Often the older adults show pathological signs of the central nervous system (CNS) in magnetic resonance imaging (MRI) but their functional importance and association with the complaint is often poorly documented and understood. In clinical history of the duration of the attacks provides some cues; vertigo associated with verteobasilar insufficiency causing cerebral ischemia typically lasts minutes and is associated with head rotation or position, whereas peripheral inner ear causes of recurrent vertigo typically last hours and are worsened by rapid turns of the head. Provoking factors such as positional changes and their association with other complaints have to be queried. In neuro-otological examination, vertical nystagmus in its classical concept suggests a central cause of dizziness (Brandt and Dietrich, 2005). It is suggested that central positional nystagmus is nearly always purely vertical (either up-beating or down-beating), and there are usually associated neurological findings, however this has recently been challenged (Cambi et al., 2013).

Baloh (1998) established the main guidelines for distinguishing between the peripheral and central causes of vertigo. Patient history, symptoms, durations and occurrence will usually guide the physician to a proper diagnosis. Cerebellar infarction can be falsely diagnosed as a peripheral vestibular lesion because vertigo and severe imbalance may be the only presenting features. Using MRI, distinct cerebellar-brain stem lesions can be ruled out. Patients with chronic recurrent attacks of vertigo often have normal clinical examination results. In rare cases positional vertigo can be a symptom of a central lesion, particularly one near the fourth ventricle.

Memory functions

It has been reported in several studies that dementia and other cogntional dysfunctions increase dizziness, vertigo and balance problems among the older adults (Allan et al., 2006). This also increases the risk for falls by decreasing avoidance reactions, orientation of surroundings and physical activity (Allan et al., 2005; Nakamura et al., 1996; Thurman et al., 2008).

In a study by Nakamura et al. (1996), it was concluded that patients with Alzheimer’s disease, walking speed and stride length were significantly lower. The stride length variability was significantly higher than in mild-stage Alzheimer type patients.
Shin et al., (2011) compared 87 subjects with either mild cognitive impairment (MCI) or non-mild cognitive impairment (non-MCI) with posturographic measurements. Study groups mean ages were 72.1 ± 4.1 years and 71.5 ± 3.7 years. They concluded that the medio-lateral (ML) sway speed and distance were higher in the MCI group than the non-MCI group, with both opened and closed eyes.

2.2 Falls in the older adults

2.2.1 Incidence of falls

In a study by Blake et al., (1988) out of 1042 community-dwelling older adults aged 65 years and over, 356 (35 %) reported one or more falls in the preceding year. Additionally, in a study by Gassmann et al., (2009), 107 (17.2 %) of 622 community-dwelling people aged ≥ 65 years reported falling at least once in the previous six months. Thirty-six (5.7 %) subjects fell twice or more during the study period.

Downton et al., (1991) studied 203 community-dwelling older adults of 75 years and over. Within the previous 12 months, 86 subjects (42.4 %) had suffered one or more falls, and of the fallers 49 (59.3 %) incurred injury, nine of them seriously. Pluijm et al., (2006) performed a three-year prospective study to identify those community-dwelling older adults with a high risk of recurrent falls. Out of 1365 community-dwelling older adults aged 65 years and older, the incidence of recurrent falls at the three-year follow-up point was 24.9 % in women and 24.4 % in men. Of the respondents, 5.5 % reported a total of 87 fractures that resulted from a fall, including 20 hip fractures, 21 wrist fractures and seven humerus fractures.

Stalenhoef et al., (2002) undertook a cohort study among 311 community-dwelling older adults aged 70 years or over to determine the risk factors for recurrent falls. During a 36-week follow-up, 197 falls were reported by 33 % of the participants: one fall by 17 % and two or more falls by 16 %. Injury due to a fall was reported by 45 % of the fallers: 2 % hip fractures, 4 % other fractures and 39 % minor injuries.

Prudham and Evans (1981) reported the fall prevalence rate among community-dwelling older adults aged 65 and over as being 28 % in the preceding 12 months. In 2793 respondents the fall rate was twice as high amongst women as men. Rates increased with age but more steeply in men than women. In a study by Tinetti et al., (1988) falls occurred in 108 subjects (32 %) out of 336 community-dwelling older adults ≥ 75 years of age during the one year follow-up period. Twenty-four percent of the fallers had serious injuries and 6 % sustained fractures. Table 3 demonstrates the fall rates among community-dwelling older adults.
Table 3. Falls among community dwelling older adults

<table>
<thead>
<tr>
<th>Study</th>
<th>Falls (%)</th>
<th>Time Frame</th>
<th>Age</th>
<th>Number of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blake et al., (1988)</td>
<td>35 %</td>
<td>12 months</td>
<td>&gt; 65</td>
<td>1042</td>
</tr>
<tr>
<td>Downton et al., (1991)</td>
<td>42 %</td>
<td>12 months</td>
<td>&gt; 75</td>
<td>203</td>
</tr>
<tr>
<td>Gassmann et al., (2009)</td>
<td>17 %</td>
<td>Six months</td>
<td>&gt; 65</td>
<td>622</td>
</tr>
<tr>
<td>Pluijm et al., (2006)</td>
<td>25 %</td>
<td>Three years</td>
<td>&gt; 65</td>
<td>1365</td>
</tr>
<tr>
<td>Prudham and Evans (1981)</td>
<td>28 %</td>
<td>12 months</td>
<td>&gt; 65</td>
<td>2793</td>
</tr>
<tr>
<td>Stalenhoef et al., (2002)</td>
<td>33 %</td>
<td>Nine months</td>
<td>&gt; 70</td>
<td>311</td>
</tr>
<tr>
<td>Tinetti et al., (1988)</td>
<td>32 %</td>
<td>12 months</td>
<td>&gt; 75</td>
<td>336</td>
</tr>
</tbody>
</table>

2.2.2  Risk factors for falls

Falling incident in the older adults can be affected by intrinsic factors (e.g. lower extremity weakness, balance disorders, dizziness, functional and cognitive impairments and visual deficits) and/or extrinsic (e.g. medications and environment) factors (American Geriatric Society 2001). Especially in the older adults the intrinsic factors effecting a fall can be diverse (Campbell and Robertson, 2006; Tinetti et al., 2006; Jäntti et al., 1995).

It is widely proven that institutionally residing older adults have a higher risk for falls (Baker and Harvey 1985). The most common precipitating factors for falls in institutions include gait and balance disorders, weakness, dizziness, environmental hazards, confusion, visual impairment and postural hypotension (Rubenstein et al., 1994). Deandrea et al., (2013) investigated risk factors for falls in institutionally residing older adults and older hospital inpatients in a systematic review. For nursing home residents, the strongest associations were with a history of falls, walking aid use and moderate disability. For hospital inpatients, the strongest association was with a history of falls.

In community-dwelling older adults Pluijm et al., (2006) identified predictors for recurrent falls: two or more previous falls, dizziness, functional limitations, weak grip strength, low body weight and fear of falling. In addition, Gassmann et al., (2009) found risk factors for recurrent falls among 107 community-dwelling older adults (over 65 years): age, female-gender, living alone, poor health status, dementia, depression, sleeping problems, incontinence, dizziness and three or more medical conditions. Two of the strongest predictors were reported falls and recurrent falls in the last six months.

Vind et al., (2010) identified three independent predictors for falls among 392 community-dwelling older adults studied in the emergency department. Predictors
were having ≥ 3 falls in the previous year, an Activities Balance Confidence Scale (ABCS) score below the median and the use of anxiolytics within the previous year. The presence of at least one of the predictors was identified among 74 % of those who fell and among 84 % of those who fell twice or more.

Impaired vision is a proven risk factor for falls. Jack et al., (1995) evaluated 200 older adults admitted to a hospital with an acute medical illness. In 101 patients with impaired vision, there was a particularly high prevalence (76 %) of those who were admitted as a result of falls. Ivers et al., (2002) studied 1081 older adults who had fallen with visual acuity test, contrast sensitivity test and visual field test. They concluded that older adults with visual acuity worse than 20/30, worsened contrast sensitivity and lowered visual field had a statistically significant association with two or more falls. They also concluded that the presence of posterior subcapsular cataract and use of non-miotic glaucoma medication had a statistically significant association with two or more falls.

Older adults with dementia or other progressive cognitive impairment are in higher risk for falls. Buchner and Larson (1987) studied falls and fractures among 117 patients with Alzheimer’s disease. Falls, fractures and medical conditions were followed for three years. During follow-up, 50 % either fell or became unable to walk. Both Alzheimer’s disease and comorbid conditions contributed to the risk of falls and fractures. Patients who experienced adverse effects to drugs were more likely to report they had fallen and patients who wandered were more likely to sustain fractures.

Van Doorn et al., (2003) studied falling rates among 2015 nursing home residents in a two-year follow-up study. The falling rate among residents with dementia was 4.05 falls per year, and 2.33 falls per year for those without dementia. Demented residents were also more likely to have an injury due to their falls. Researchers concluded that demented nursing home residents should be included in fall-prevention and fall-injury-prevention strategies.

Dizziness and falls
Disabilities and consequences caused by dizziness become more severe in old age, causing falls, fall-related injuries and isolation. Dizziness and vertigo have been regarded as significant predictors for falls. Rubenstein et al., (1994) reported balance disorders and dizziness as the second and third leading causes of falls in older adults. Dizziness, unsteadiness and related symptoms also have an indirect effect on health and often cause a fear of falling (Burker et al., 1995). Furthermore, dizziness and vertigo in the older adults lead to a reduction of both mental and physical health (Grimby and Rosenhall, 1995).
Dizziness was the leading risk factor for falls in a follow-up study conducted by O’Loughlin et al., (1993) when compared to other risk factors such as frequent physical activity, having trouble walking 400 m distance and having trouble bending down. Falls were associated with dizziness and vertigo in 7–15 % of the older adults in a study by Jönsson et al., (2004). The prevalence of falls was greater in the females than in the males. Twenty-six percent perceived their vertiginous problem as posing an obstacle to the daily activities.

Collerton et al., (2012) studied the prevalence and impact of falls, and the overlap between falls, dizziness and blackout among 816 older adults aged 85 years and older. Over 38 % of participants had fallen at least once in the previous 12 months and 10.6 % sustained a fracture. 'Worry about falling' was experienced by 42.0 % of the fallers. Dizziness and blackouts were reported by 40.0 % and 6.4 % of participants respectively. There was a marked overlap in the report of falls, dizziness and blackouts.

**Medication**

Medication and especially polypharmacy are well acknowledged risk factors for falls among older adults. In a meta-analysis by Woolcott et al., (2009) the impact of nine unique medication classes on falls in older adults were reviewed. Meta-analysis consisted 22 articles and 79 081 participants older than 60 years. An increased likelihood of falling was estimated for the use of sedatives and hypnotics, neuroleptics and antipsychotics, antidepressants and benzodiazepines.

Leipzig et al., (1999, I) did a meta-analysis and review on psychotropic drugs and falls. They concluded that there is a small, but consistent association between the use of most classes of psychotropic drugs and falls in older adults. However, they also concluded, that the associations need to be further studied with comprehensive randomized controlled trials. Leipzig et al., (1999, II) also published the same year a meta-analysis and a review on the cardiac and analgesic drugs’ connection to falls in older adults. They concluded that more than three or four medications increased the risk of recurrent falls and because of the severity of the consequences of falls among the older adults, programs designed to decrease medication use should be evaluated for their impact on fall rates. They also concluded that digoxin and diuretic use are associated weakly with falls in older adults.

Hartikainen et al., (2007) did a review on medication as a risk factor for falls. They included 28 observational studies and one randomized controlled trial. The main group of drugs associated with an increased risk of falling was psychotropics: benzodiazepines, antidepressants and antipsychotics. Antiepileptics and drugs that lower blood pressure were weakly associated with falls.
Bloch et al., (2011) conducted a meta-analysis on psychotropic drugs and falls among older adults including 71 articles. The analysis confirms the previous findings on psychotropics and falls. They also conducted that the odds ratios were nearly double in the group “traumatic falls” compared to the group “all falls” for neuroleptic drugs, antidepressants and benzodiazepines.

2.2.3 Consequences of falls

Accidental falls are one of the leading causes of death among the elderly population, surpassing even those due to car accidents (Korhonen et al., 2011). Injuries are the sixth leading cause of death in the 75 years-and-over population, with falls the leading cause of injury-related deaths (Baker and Harvey, 1985). More than a third of older adults fall each year and 10–20 % of falls cause serious injuries such as fractures or head traumas. Severities of fall-related injuries are considerably higher in the older population (Sterling et al., 2001).

Fall incidence among institutionally residing older adults is higher and they have a disproportionately high incidence of hip fractures and higher mortality rates after hip fractures than community-dwelling older adults (Jäntti et al., 1993; Rhymes and Jaeger, 1988; Tinetti, 1987). Furthermore, because of the high frequency of recurrent falls among adults living in an institution, the likelihood of sustaining an injurious fall is substantial (Rapp et al., 2010).

It is widely proven that falls in the older adults lead to increased fear of falling, avoidance of activities and isolation (Howland et al., 1998; Tinetti et al., 1994). Social isolation and inactivity threatens quality of life among older adults suffering from fear of falling (Li et al., 2003).

2.2.4 Preventing falls

Multi-factorial falling interventions have been successful in some, but not in all prevention trials (Gates et al., 2008). The American Geriatric Society (2001) viewed that preventing falls in populations requires firstly the selection of the population most likely to benefit, and also the selection of the particular interventions that are shown to be effective in that group. Delbaere et al., (2010) concluded that many older adults either underestimated or overestimated their risk of falling. They suggested that physical, cognitive and psychological measures should be included within any fall risk assessment.

Neyens et al., (2011) undertook a systematic review about the effectiveness of the fall interventions in older adults in long-term care facilities. Twenty trials were
included the review. In seven trials, there was a significant reduction in the fall rate, the percentage of recurrent fallers and the incidence of femoral fractures. The programs with positive effect were: 1. Structured individual assessments with safety recommendations; 2. Multi-disciplinary programs including general strategies tailored to the setting and residents; 3. Multi-faceted interventions including education, environmental adaptation, balance, resistance training and hip protection; 4. Calcium and/or vitamin D supplementation; 5. Clinical medication review; 6. Multi-factorial interventions including fall risk evaluation, specific and general interventions. Most of the reviewed studies did not find a significant positive effect on fall incidents. They concluded that multi-factorial interventions among the older adults living in residential home facilities seem more likely to be beneficial. However, single interventions (e.g. targeting vitamin D insufficiency) can be effective.

In a Cochrane review of fall intervention programs among community-dwelling older adults conducted by Gillespie et al., (2012), 159 trials with 79193 older adults were included. Multiple-component group exercise significantly reduced the rate of falls and the risk of falling, as did multiple-component home-based exercise. Risk of falling ratio was used as the treatment effect comparing the number of people who fell once or more. Multi-factorial interventions which included individual risk assessment reduced the rate of falls, but not the risk of falling. Falls and risk of falling were reduced with home safety assessment, and modification interventions were effective in reducing the rate of falls and risk of falling. Pacemakers reduced the rate of falls in people with carotid sinus hypersensitivity but not the risk of falling. First eye cataract surgery in women reduced the rate of falls, but second eye cataract surgery did not. Gradual withdrawal of psychotropic medication reduced the rate of falls but not the risk of falling. A prescribing modification program for primary care physicians significantly reduced the risk of falling, and an anti-slip shoe device reduced the rate of falls in icy conditions.

Falls in the older adults in residential or nursing care facilities and hospitals are common events that may cause loss of independence, injuries and sometimes death as a result of injury. Effective interventions to prevent falls are important as they will have significant health benefits. Cameron et al., (2012) conducted a Cochrane review of fall intervention programs among institutionally residing older adults. It consisted 60 trials involving 60345 participants in care facilities and hospitals. Despite the large number of trials, the overall results were inconclusive. Results from 13 exercise interventions showed different results. They concluded that exercise programs increase falls in frail residents and reduce falls in less frail residents and interventions targeting multiple risk factors may be effective in reducing the number of falls. Physiotherapy reduced the number of falls in hospital
rehabilitation wards and interventions targeting multiple risk factors reduced falls in hospital wards.

Izumi et al., (2002) proposed that the best objective predictors of “a potential faller” are a history of previous falls, the need for assistance while moving and the nurses’ predictions. There is also a well-accepted belief that a focused history and physical examination after a fall can determine the immediate underlying causes of the fall and that these can be targeted for specific treatment and prevention strategies (Rubenstein et al., 1994).

Many studies have shown that exercise programs are beneficial to even the severely demented older adults population. Heyn et al., (2004) studied the effects of a physical exercise program among older adults with dementia or other cognitive impairment in a meta-analysis of 30 trials including 2020 subjects. They concluded that exercise training increases fitness, physical function, cognitive function and positive behavior in people with dementia and related cognitive impairments.

Rolland et al., (2007) studied the effectiveness of an exercise program in improving the activities of daily living – score (ADL-score), physical performance and nutritional status, and in decreasing behavioral disturbance and depression in patients with Alzheimer’s disease. The study included 134 subjects with mild to severe Alzheimer’s disease. The authors concluded that with a simple exercise program of one hour twice a week, the ADL-score declined significantly more slowly.

Brill et al., (1995) studied strength and flexibility training programs conducted in nursing homes with subjects with dementia. At the end of the 11-week training program, improvements were seen in both strength and flexibility among the demented residents.

2.2.5 Posturographic measurements in fall risk evaluation

Fujita et al., (2005) analyzed the effect of age on body sway using posturography. They studied 144 subjects between the ages of 22–88 years and concluded that swaying on the force platform increased with advancing age. Tracking density per unit area expressed that the efficiency of postural control decreased with age, but only when the subjects had their eyes open – this decrease did not occur when they had their eyes closed.

In posturography, the center point of force has been commonly used to characterize the subjects’ ability to control posture and is used in analysis to quantify the body position and the sway path (length) or sway area during certain periods of time. Both these parameters are related to postural performance (Rasku et al., 2012, I). In the older adults, body sway is random in contrast to that of younger residents in whom
body sway is predictive and the subjects seem to oscillate around an attractor (Rasku et al., 2012, II).

Buatois et al., (2006) studied the predictive value of posturographic tests (Static Test, Slow Dynamic Test, Sensory Organization Test) in the estimation of the risk of recurrent falls, including a comparison with clinical balance tests (‘Timed Up and Go’- Test, ‘One-Leg Balance’- Test, ‘Sit-to-Stand’- Test) among 206 healthy non-institutionalized older adults over 65 years of age. They concluded that the Sensory Organization Test, especially with repetition of the same task in sensory conflicting conditions, appears to be a more sensitive tool to identify those at a high risk of recurrent falls when compared to the clinical tests and the static and dynamic posturographic tests.

Pyykkö et al., (1990) studied the postural stability of the oldest adults (n = 23) using a force platform in different sensory feedback conditions. The sensory function of the lower limbs was disturbed with small vibrators on both calf muscles. When compared with a group (n = 100) of 50–60-year-old adults, the older adults had significantly higher sway velocities even during non-perturbed conditions. They concluded that the oldest adults seem to rely mostly on visual control of posture and a deficit of structured visual surroundings can be one important reason for falls amongst this group.

Colledge et al., (1994, I) conducted measurements with static posturography among 74 healthy subjects in four age groups: 20–40, 40–60, 60–70 and over 70 years. Sway increased linearly with age. All age groups were more dependent on proprioception than vision in the maintenance of balance, but when reliable pressoreceptor information was removed, their dependence on vision increased. They concluded that an increase in sway in normal ageing is more likely due to a slowing of central integrative processes.

2.3 Conclusion of literature review

It is a well-known fact that dizziness causes falls and leads to isolation and decreasing in quality of life especially in the older population. Dizziness, vertigo and balance problems in the older adults is usually associated with orthostatic hypotension, medication or frailty. Factors causing these symptoms have been extensively studied and have led into wide range of preventive actions in nursing homes. However there are limited amount of results about vestibular and posturographic findings among institutionally residing and community-dwelling older adults. Fall intervention studies’ reviews have presented different kind of results of the effectiveness of training programs among older adults.
3 AIMS OF THE STUDY

The study aimed to determine factors of dizziness/vertigo and balance problems among community-dwelling and institutionally residing older adults using extensive symptom questionnaires, neuro-otological examination and posturographic measurements. The aim was also to evaluate the effectiveness of a three-month muscle and balance exercise intervention program with falls, balance and quality of life among the older adults residing in an institutional setting.

The specific aims were:

To characterize the factors of vertigo/dizziness and balance problems and their association with falls, quality of life and mini-mental state examination (MMSE) among older adults residing in institutional settings.

To evaluate vertigo/dizziness and balance problems and vestibular functions in older adults residing in institutional settings with neuro-otological examination and posturographic measurements.

To evaluate the effect of guided exercise on postural stability, falls and quality of life among the older adults residing in an institutional setting.

To evaluate factors associated with falls in community-dwelling older adults using an otoneurological case history, a general health related quality of life measure, a fall history from the last three months and posturographic measurements.
4 MATERIALS AND METHODS

4.1 Persons studied

The study was performed in Tampere, Finland during 2004–2009. Otoneurological interview, video-oculography with neuro-otological examination and posturographic measurements among the institutionally residing older adults were conducted in 2004–2006. Otoneurological interview and posturographic measurements for the community-dwelling older adults were conducted in 2007–2009. Of the 896 residents in the Koukkuniemi home for the older adults, subjects were selected by the nurses on the basis of the patient’s willingness to participate in the study and their demonstrated ability to rise to standing from a chair without outside help. The study among the community-dwelling older adults was carried out among members of the Pensioner Association in the city of Tampere who encouraged members to volunteer to participate in the study. The City of Tampere institutional review board approved the study protocol among both study groups. Written consents were gathered before commencing the study from everyone. The organization of the study groups is presented in Figure 1. The characteristics of the study groups are presented in Tables 4 and 5.
156 Institutionally residing older adults enrolled the study.

84 either became ill, died, were moved into another facility or changed their minds about participation.

72 subjects continued to otoneurological questionnaire.

13 either became ill, died or were moved into another institution.

59 continued to rehabilitation intervention. Four participants died before commencing the training.

55 continued to the training. Before the end of the training, six residents stopped the training. Forty-nine completed the three-month training.

38 continued to neuro-otological testing which was commenced after the rehabilitation intervention.

96 community-dwelling older adults enrolled the study.

All 96 subjects participated to the otoneurological questionnaire.

Posturography measurements were conducted to 96 subjects.

Due to hard drive failure 29 posturography results were lost.

From 67 community-dwelling older adults posturographic measurements were analyzed.

**Figure 1.** Organization of the study groups
<table>
<thead>
<tr>
<th></th>
<th>Vertigo/dizziness and balance problems characterization n = 72</th>
<th>Fall prevention Training n = 55</th>
<th>Neuro-otological testing n = 38</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td>Mean age (range)</td>
<td>87 (70–101)</td>
<td>86 (70–102)</td>
<td>89 (80–103)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Female</td>
<td>58 (81)</td>
<td>42 (76)</td>
<td>31 (82)</td>
</tr>
<tr>
<td>Alcohol</td>
<td></td>
<td></td>
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<tr>
<td>No alcohol</td>
<td>63 (87)</td>
<td>48 (88)</td>
<td>29 (76)</td>
</tr>
<tr>
<td>Under 4 doses per week</td>
<td>4 (6)</td>
<td>3 (5)</td>
<td>5 (13)</td>
</tr>
<tr>
<td>5–9 doses per week</td>
<td>3 (4)</td>
<td>3 (5)</td>
<td>4 (11)</td>
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<tr>
<td>10–20 doses per week</td>
<td>2 (3)</td>
<td>1 (2)</td>
<td>0 (0)</td>
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<tr>
<td>Regularly used medication</td>
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<tr>
<td>Diuretics</td>
<td>49 (68)</td>
<td>40 (73)</td>
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<tr>
<td>NSAIDs</td>
<td>55 (76)</td>
<td>43 (78)</td>
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<tr>
<td>Antidepressants</td>
<td>44 (61)</td>
<td>33 (60)</td>
<td>22 (58)</td>
</tr>
<tr>
<td>Sleeping medication (Benzodiazepines)</td>
<td>43 (60)</td>
<td>30 (55)</td>
<td>13 (34)</td>
</tr>
<tr>
<td>Diseases</td>
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<tr>
<td>MCC</td>
<td>32 (44)</td>
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<tr>
<td>Hypertension</td>
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<td>DM 1&amp;2</td>
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<td>8 (15)</td>
<td>5 (13)</td>
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<td>Hypo/ hyperthyreosis</td>
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<td>MMSE-score</td>
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<td>MMSE 27–30</td>
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<td>MMSE 11–20</td>
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<tr>
<td>MMSE 0–10</td>
<td>4 (6)</td>
<td>3 (5)</td>
<td>2 (5)</td>
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</table>
Table 5. Characteristics of the 96 community-dwelling older adults

<table>
<thead>
<tr>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Mean Age (range)</td>
<td>70</td>
<td>(60–85)</td>
</tr>
<tr>
<td>Gender n (%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>53</td>
<td>(55 %)</td>
</tr>
<tr>
<td>Alcohol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No alcohol</td>
<td>27</td>
<td>(28 %)</td>
</tr>
<tr>
<td>Under 4 units per week</td>
<td>55</td>
<td>(57 %)</td>
</tr>
<tr>
<td>5–9 doses per week</td>
<td>13</td>
<td>(14 %)</td>
</tr>
<tr>
<td>10–20 doses per week</td>
<td>1</td>
<td>(1 %)</td>
</tr>
<tr>
<td>Regularly used Medications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diuretics</td>
<td>45</td>
<td>(47 %)</td>
</tr>
<tr>
<td>NSAIDs</td>
<td>48</td>
<td>(50 %)</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>8</td>
<td>(8 %)</td>
</tr>
<tr>
<td>Sleeping medication</td>
<td>20</td>
<td>(21 %)</td>
</tr>
<tr>
<td>Diseases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCC</td>
<td>14</td>
<td>(15 %)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>50</td>
<td>(52 %)</td>
</tr>
<tr>
<td>Kidney dysfunction</td>
<td>2</td>
<td>(2 %)</td>
</tr>
<tr>
<td>DM 1&amp;2</td>
<td>7</td>
<td>(7 %)</td>
</tr>
<tr>
<td>Hypo or hyperthyrosis</td>
<td>7</td>
<td>(7 %)</td>
</tr>
</tbody>
</table>

4.2 Assessments

4.2.1 Otoneurological questionnaire

The otoneurological questionnaire consists of various questions about medical history, medication, symptoms of vertigo/dizziness and balance problems (Kentala et al., 1999) (Appendix A). Otoneurological questionnaire was interviewed by one researcher (ET) in the institutionally residing older adults group. When necessary, the subjects’ interviews were confirmed or augmented by interviews with their personal nurses who served as proxies. Additionally, subjects’ medical records were reviewed to obtain a complete medical history including all confirmed medical diagnosis and
medications. For the community-dwelling older adults study group the questionnaire was sent to subjects’ home address before the posturographic testing. Before the posturography testing the questionnaire was checked by one examiner (ET).

Dizziness and vertigo in the otoneurological questionnaire were broken down into more detail as rotatory vertigo/dizziness, movement instability, fear of falling, sudden loss of balance, light-headedness, floating sensation and/or black-out. In addition, some related symptoms such as a feeling of unreality, loss of vitality, nervousness and reduced mobility were queried. The occurrence of vertigo, duration of spells and provoking factors were asked. Symptoms of hearing loss, tinnitus and associated symptoms, such as nausea or vomiting were queried. Finally, the effect of vertigo or dizziness on a subjects’ everyday life was evaluated.

The occurrence of these symptoms (either isolated or in combination) was studied and their severity was evaluated using more detailed questions that further characterized the symptoms. Patient charts were reviewed for neurological symptoms and disorders including possible attacks of syncope or near syncope and any malfunction of specified cranial nerves. Subjects’ moving ability was addressed with four questions. These focused on the older adults’ ability to walk and stand when not acutely affected by vertigo spells and inquired about the general severity of any balance problems. Possible injuries to the inner ear were addressed with questions that focused on ear infections, chronic noise exposure, acoustic trauma or ear surgery. One interview took altogether approximately 60 minutes and low MMSE scores did not exclude any subjects from the interview.

Among the community-dwelling older adults the level of daily exercise/activities were included into the otoneurological questionnaire (Appendix A). Exercise was identified vigorous-intensity activity such as walking, dancing, gardening or planned exercise. Number of weekly exercise/activity was queried with five choices from which the subjects could choose from. Options were: no exercise, exercise once a week, exercise twice a week, exercise three times a week, exercise more than three times in a week.

4.2.2 Quality of life questionnaires

Health-related quality of life (HRQoL) includes physical and mental health perceptions and their correlates, including health risks and disabilities, functional status, social support and socioeconomic status.

The QoL-15D instrument is a generic, comprehensive, 15-dimensional, standardized, self-administered measure of health-related quality of life that can be used both as a profile and single index score measure (Appendix B). Sintonen (2001) examined...
The QoL-15D questionnaires usability and validity, and reviewed it as being highly reliable, sensitive and responsive to change, generalizable at least in Western-type societies, and particularly valid for deriving a measure of quality-adjusted life years (QALYs) for resource allocation purposes.

The QoL-15D is a widely-used method to assess general HRQoL; it consists of 15 questions, each graded to five levels (Auramo et al., 1995; Juhola et al., 2001; Kentala et al., 1999; 2001). Questionnaire describes the health status, assessing 15 dimensions, namely: mobility, vision, hearing, breathing, sleeping, eating, speech, elimination, usual activities, mental function, discomfort and symptoms, depression, distress, vitality and sexual activity. Each dimension comprises one question with five answer options. A single index score (the QoL-15D score) is obtained by incorporating population-based preference weights to the dimensions. The final score is between 0 and 1, where 0 indicates a condition akin to death and 1 a full, complaint-free life. The instrument is designed to establish the degree to which patients are content with their lives and abilities. For example, the question about mobility is rated as follows: 0 = I can walk normally; 1 = I can walk with little difficulty; 2 = I can walk with notable difficulties; 3 = I can only walk a little; and 4 = I am unable to walk. Among the various selections of quality of life tools, the QoL-15D instrument was chosen, because it has been proven to be a useful tool assessing quality of life also among older adults living in an institution (Pitkälä et al., 2008).

The QoL-15D questionnaire was administered among the institutionally residing older adults by personally interviewing the subjects by one researcher (ET). One interview took approximately 20 minutes and dementia or other cognitive dysfunctions did not exclude any subjects from the interview. When necessary, the subjects' interviews were confirmed or augmented by interviews with their personal nurses who served as proxies. The interview was conducted in the beginning of the training, after the training had ended and six months after the training had begun.

Among the community-dwelling older adults we used the shorter quality of life questionnaire EQ-5D (The Euroqol group, 1990) (Appendix C). The instrument consists of two parts: One comprises five questions related to the patients functional capacity (time trade off (TTO) instrument) and the other is a thermometer (visual-analogue scale, VAS). The five quality of life dimensions in the questionnaire are mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each question had three options from which the subjects to choose from. In the VAS component, the patient is asked to indicate a self-rating of their current health status. In the community-dwelling older adults group the EQ-5D questionnaire was sent to the subjects home address beforehand and checked together with the researcher.
(ET) before the posturographic measurements. The EQ-5D is commonly used to measure HRQoL and has been shown to be responsive and reliable in the normal population and older adults (Holland et al., 2004; Wolfs et al., 2007).

4.2.3 Falls

World Health Organization (WHO Global Report on Falls Prevention in Older Age, 2007) defines falls as inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects. In the institutionally residing older adult group the number of falls was collected from the wards using a questionnaire filled out by the nursing staff (Appendix D). The questionnaire was completed in case of a fall and consisted of questions about the conditions of the fall (own room, bathroom, day or night), whether the subject was using walking aids, did the fall have eyewitnesses, and if there were any symptoms before and after the fall. The number of falls was collected for three years from the beginning of the study period. Number of falls in the community-dwelling older adults group was queried as separate questionnaire sent before the posturographic testing. The number of falls was collected for three previous months before the measurements.

4.2.4 Fear of falling

The Falls Efficacy Scale International (FES-I), developed and validated by the Prevention of Falls Network Europe (ProFaNE), has become a widely accepted tool for assessing concern about falling (Yardley et al., 2005) (Appendix E). The FES-I provides information on level of concern about falls for a range of activities of daily living. The questionnaire contains 16 items scored on a four-point scale (1 = not at all concerned to 4 = very concerned). The FES-I questionnaire was conducted in the institutionally residing older adults by personally interviewing the subjects by one researcher (ET) and it was interviewed within the same session with the otoneurological questionnaire. Community-dwelling older adults filled the FES-I themselves before the posturographic measurements.

4.2.5 Mini Mental State Examination

The Mini Mental State Examination score measures cognitive ability (attention, memory, language, calculations) with a maximum score of 30 (Appendix F). Any score greater than or equal to 27 points can be considered as a normal cognition.
Below this, scores can indicate mild to severe cognitive impairment (Folstein et al. 1975). The MMSE-testing was administered for the institutionally residing older adults by their personal nurses. The MMSE-testing was not commenced among the community-dwelling older adults.

4.2.6 Neuro-otological examination and video-oculography

Neuro-otological examination was conducted with the help of video-oculography (VOG) (Micromedical Technologies, Chatham, Illinois, USA). In the test, eyes were covered by transparent video-goggles. Subjects could visualize their surroundings and fix their gaze on objects. Their eyes were illuminated with infrared lamps within the video goggles for presentation on a video monitor. The VOG signal was sampled at a frequency of 25 Hz and fed into a portable computer. Internal algorithms calculated the position and movement of the iris in order to quantify the eye movements.

The VOG was calibrated with a light bar placed 1.2 meters in front of the subject, covering a visual field of 40 degrees. The light bar consisted of ‘light-emitting diodes’ (LEDs) illuminated by the program and the calibration was made with alternating saccades at 20 degrees of visual angle.

The function of the vestibulo-ocular reflex can be crudely evaluated with VOG during fixation (vestibule-visual interaction, VVOR) and then in the darkness when the head is turned from side to side about 20 degrees from the centerline, at a pace of 1 Hz. Normally the gaze (and the eye position) will be in the center position and no fast phases of nystagmus are present. Any asymmetry or significant function loss will reveal itself by eye deviation or saccades in the test. In cases of severe function loss, the eyes follow the head without providing compensatory movement. The testing for one subject took approximately 30 minutes and was conducted by one examiner (IP). All of the neuro-otological tests could not been performed to all of the subjects due to nausea, tiring and current frail health status.

The following neuro-otological tests were conducted using VOG

1. Spontaneous nystagmus
2. Dix-Hallpike test
3. Lateral Gaze (20–30 degrees)
4. Head-shaking test
5. Head thrust test
6. Saccades
7. Smooth pursuit
4.2.7 Posturography

A custom-made force platform was used to measure the vertical force distribution over the platform surface. From this force distribution, the postural stability range, elliptic area, force moments and sway velocity can be analyzed in both visual and non-visual conditions, from which Romberg’s quotient can be calculated. During the test, the subject stands without shoes, knees locked, and arms crossed over the chest on the solid platform surface. Feet were placed on marked footprints in the platform surface and eyes are fixated forward looking at a reference point. Tests were explained to subjects and rehearsed once before actual testing. Among the institutionally residing older adults rehabilitation intervention group, posturography was carried out before the training, immediately after the training and at three months after the training. For the community-dwelling older adults posturographic measurements were conducted only once. All the measurements for both of the group of older adults were conducted by one researcher (ET).

4.3 Rehabilitation intervention

Randomization

Randomization was done by allotting the participants into three different exercise intervention groups using the sealed envelopes system. After the subjects had given their consent to participate the study, they opened an envelope consisting the training groups’ name. Groups were blinded to the researcher until the end of the follow-up period.

Training

The institutionally residing older adults were randomized into three different training groups (Table 6). Training was undertaken in five person groups under the supervision of physiotherapists. Exercises were twice a week, one hour at a time for 26 sessions over 13 weeks. The average attendance rate was 23 out of 26 sessions.
### Table 6. Exercises in different training groups

<table>
<thead>
<tr>
<th>Exercise focus</th>
<th>Muscle force training n = 16</th>
<th>Balance and muscle force training n = 14</th>
<th>Self-administered training n = 19</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increasing the muscle strength of the lower extremities.</td>
<td>Increasing the muscle strength of the lower extremities and enhancing balance.</td>
<td>Increasing the muscle strength of the lower extremities and enhancing balance.</td>
</tr>
<tr>
<td>Exercise content</td>
<td>Stretching of each leg in the sitting position, standing up exercises, squat to standing beside parallel bars, three repeats of side steps to the left and right, standing on tiptoes, alternate raising of both knees by supporting themselves on a parallel bar.</td>
<td>Stepper exercise, blind walking in square bracket, blind walking straight, bean bag stretching exercise (from squat to tiptoe). Balance board, ball bouncing, ball throwing and catching, walking on line beside a parallel bar, walking with head turning from side to side and head nodding.</td>
<td>Training consisted of three exercises; stretching of each leg, leg raises and crouching and rising from a sitting position. Instructions were given in written form and were supervised twice a week by geriatric nurses on the ward.</td>
</tr>
<tr>
<td>Exercise development</td>
<td>From the sixth training onwards, 1.2 kg weights were fixed to the ankles. From the ninth training onward, whilst standing, exercises included knee raising and knee flexion and extension on training equipment, squat to standing, and exercises on a stepper board. From the 19th exercise session onwards, training to walk up a staircase was added.</td>
<td>From the third session onwards, walking with a beanbag on the head was added. From the ninth session onwards, a stepping exercise was added, blind walking and a bean bag stretching exercise (from squat to tiptoe). From session 18 onwards, a trampoline, balance board, ball bouncing, ball throwing and catching, walking on a line beside the parallel bar, and walking while turning the head side to side</td>
<td>Training content stayed the same during the study period.</td>
</tr>
</tbody>
</table>

### 4.4 Statistical analysis

All the statistical analysis was done using the SPSS software (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.).

Factor analysis was used in studies I, II and IV. The analysis was done by using the vertigo/dizziness symptoms and associating factors reported in the otoneurological questionnaire. With varimax rotation common indicators of vertigo/dizziness
and balance problems among institutionally residing and community-dwelling older adults were identified. Symptoms and associated factors used in the analysis were; type of vertigo/dizziness, postural instability, tendency to fall, syncope, frequency, duration and intensity of the vertigo/dizziness spells, nausea, provoking factors and movement restrictions associated to vertigo/dizziness. Factors were further analyzed to find associations with fear of falling in FES-I, different components of quality of life, mortality, falls, MMSE-scores and posturography results.

In studies I and II correlation analysis was done in continuous variables using Pearson’s and in class variables Kendall’s Tau correlation analysis. In study II the Mann-Whitney U-test was used to assess differences between binary variables.

In study III differences in continuous variables between the training groups were analyzed with an analysis of variance (ANOVA) and in discrete variables with the Mann–Whitney U-test, Chi-square test, or Wilcoxon signed-rank test. Linear correlations were made and evaluated using Kendall’s Tau. In analyzing the posturography outcome and changes in QoL, a paired Student’s t-test was used. In searching for associations between risk factors and the posturography outcome ANOVA was used and in the case of binary variables, logistic regression analysis was carried out.

In Study IV the risk of falls was analyzed using a logistic regression analysis. Differences in the continuous variables were analyzed with the Student’s t-test, and in discrete variables by using a Mann–Whitney U-test or Wilcoxon Signed Rank test. The associations in continuous variables were examined with a Pearson’s test, and in discrete variables using Kendall’s tau.
5 RESULTS

5.1 Vertigo/dizziness and balance problems among older adults

5.1.1 Characteristics of vertigo/dizziness and balance problems

In order to characterize vertigo/dizziness and balance problems among institutionally residing and older adults an otoneurological questionnaire was used. Vertigo/dizziness symptoms, duration, occurrence and associating factors were queried. Subject could answer either with one or multiple answers to symptoms. In 72 institutionally residing older adults, 49 (68 %) indicated a presence of vertigo/dizziness and balance problems. Females reported these symptoms more frequently than males ($\chi^2 = 27.9$, $p < 0.001$). The majority of the institutionally residing older adults suffered from vertigo/dizziness and balance problems on a daily basis and the attack lasted for 1–20 minutes. They described their vertigo or dizziness as “moderately strong,” meaning that the subjects had to abandon their daily activities in order to manage the vertigo/dizziness. In 96 community-dwelling older adults, 42 (44 %) suffered from vertigo/dizziness and balance problems. The characteristics of these symptoms, both institutionally residing and community-dwelling older adults, are presented in Table 7.
Table 7. Characteristics of vertigo/dizziness and balance problems among institutionally residing and community-dwelling older adults.

<table>
<thead>
<tr>
<th></th>
<th>Institutionally residing older adults</th>
<th>Community-dwelling older adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>n(total)</td>
<td>72</td>
<td>96</td>
</tr>
<tr>
<td>Vertigo/dizziness and balance problems (49/72)</td>
<td>49 (68 %)</td>
<td>42 (44 %)</td>
</tr>
<tr>
<td>Symptoms (one or multiple)</td>
<td>n(total) = 49</td>
<td>Symptoms (one or multiple)</td>
</tr>
<tr>
<td>Rotation</td>
<td>21 (43 %)</td>
<td>Rotation</td>
</tr>
<tr>
<td>Floating</td>
<td>20 (41 %)</td>
<td>Floating</td>
</tr>
<tr>
<td>Feeling of falling</td>
<td>40 (82 %)</td>
<td>Feeling of falling</td>
</tr>
<tr>
<td>Instability</td>
<td>29 (59 %)</td>
<td>Instability</td>
</tr>
<tr>
<td>Blackout</td>
<td>6 (12 %)</td>
<td>Blackout</td>
</tr>
<tr>
<td>Frequency</td>
<td>n(total) = 49</td>
<td>Frequency</td>
</tr>
<tr>
<td>Less than once a year</td>
<td>2 (4 %)</td>
<td>Less than once a year</td>
</tr>
<tr>
<td>Less than once a month</td>
<td>4 (8 %)</td>
<td>Less than once a month</td>
</tr>
<tr>
<td>Monthly</td>
<td>6 (12 %)</td>
<td>Monthly</td>
</tr>
<tr>
<td>Weekly</td>
<td>15 (31 %)</td>
<td>Weekly</td>
</tr>
<tr>
<td>Daily</td>
<td>22 (45 %)</td>
<td>Daily</td>
</tr>
<tr>
<td>Duration</td>
<td>n(total) = 49</td>
<td>Duration</td>
</tr>
<tr>
<td>Under 1 min</td>
<td>7 (14 %)</td>
<td>Under 1 min</td>
</tr>
<tr>
<td>1 min–20 min</td>
<td>21 (43 %)</td>
<td>1 min–20 min</td>
</tr>
<tr>
<td>20 min–4h</td>
<td>15 (31 %)</td>
<td>20 min–4h</td>
</tr>
<tr>
<td>4h–24h</td>
<td>2 (4 %)</td>
<td>4h–24h</td>
</tr>
<tr>
<td>Constant</td>
<td>4 (8 %)</td>
<td>Constant</td>
</tr>
<tr>
<td>Intensity</td>
<td>n(total) = 49</td>
<td>Intensity</td>
</tr>
<tr>
<td>Very mild</td>
<td>1 (2 %)</td>
<td>Very mild</td>
</tr>
<tr>
<td>Mild</td>
<td>15 (31 %)</td>
<td>Mild</td>
</tr>
<tr>
<td>Moderate</td>
<td>19 (39 %)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Strong</td>
<td>12 (24 %)</td>
<td>Strong</td>
</tr>
<tr>
<td>Very strong</td>
<td>2 (4 %)</td>
<td>Very strong</td>
</tr>
</tbody>
</table>
5.1.2 Factor analysis of vertigo/dizziness and balance problems

Using the reported vertigo/dizziness symptoms from the otoneurological questionnaire, a factor analysis was performed to characterize common indicators of vertigo/dizziness and balance problems among older adults.

Among institutionally residing older adults vertigo/dizziness and balance problems were detected from 68% (49/72). In factor analysis, six major factors were found to have common components of vertigo/dizziness and balance problems. Factors were further analyzed with different dimensions of quality of life, mortality, falls within the three years follow-up period and MMSE-scores.

1. Vestibular irritability

Subjects had symptomatic paroxysmal vertigo/dizziness that was provoked by physical strain or activity and was often accompanied by nausea. Subjects also experienced sudden instability episodes. There was a correlation with a reduction of the total score of the QoL-15D ($r = 0.30, p = 0.037$).

2. Positional vertigo

Subjects suffered frequent episodes of postural instability and the episodes were provoked by position and physical strain. This correlated with reduced mobility dimension in the QoL-15D score ($r = 0.32, p = 0.006$).

3. Vestibular failure

Subjects suffered from rotatory or floating type of vertigo. This correlated with impending death ($r = 0.31, p = 0.031$) and a reduction of vitality in the QoL-15D score ($r = 0.32, p = 0.021$).

4. Frailty

Subjects had poor muscle strength and coordination in a subjective evaluation. They needed assistance or supporting devices for moving. This correlated significantly with following dimensions in the QoL-15D score: reduced ability in usual activities ($r = 0.33, p = 0.021$), reduced mobility ($r = 0.61, p < 0.001$), poor vision ($r = 0.33, p = 0.003$) and habitual falls (> 7 falls within the follow up period) ($r = 0.31, p = 0.010$). Frailty also correlated negatively with the MMSE-scores ($r = -0.28, p = 0.014$).
5. Autonomic vertigo

In this feature the subjects tended to suffer from episodes of syncope/near syncope, or intensive vertigo requiring bed rest with delayed recovery. This correlated with distress ($r = 0.51, p < 0.001$), reduction of vitality ($r = 0.31, p = 0.031$) in the QoL-score and falls within the following three years ($r = 0.25, p = 0.041$).

6. Movement intolerance

Distinctive for this feature was a constant feeling of dizziness, often with nausea. It was associated with instability but without a feeling of falling. It correlated with reduced mental functions dimension in the QoL-15D score ($r = 0.285, p = 0.012$).

Among community-dwelling older adults vertigo/dizziness and balance problems were detected from 44% (42/96). In factor analysis, four major factors were found to have common components of vertigo/dizziness and balance problems. Factors were further analyzed to find associations with the FES-I scores, posturographic measurements and falls during the previous three months.

1. Vestibular irritability/failure

The subjects reported rotatory vertigo and floating sensation. Symptoms were periodic and provoked by physical strain or activity. Nausea often accompanied the attack. Subjects' falls were provoked by change in body position such as getting up from a chair. Vestibular failure correlated with the ability to hold a neutral position in posturography ($p = 0.008$) and was in association with falls in the logistic regression analysis (OR = 1.8, $p = 0.002$).

2. Movement intolerance

Subjects suffered from mobility and gait problems associated with chronic instability. Subjects' falls were a consequence of a sudden slip or a trip. Movement intolerance correlated highly significantly with the critical time for control in open versus closed loop postural control in posturography ($p < 0.01$) and was in association with falls the in logistic regression analysis (OR = 1.8, $p = 0.002$).
3. Frailty

Subjects had postural instability, poor muscle strength and needed assistance in movements. They preferred to use their hands to assist themselves when rising from a chair and used supporting devices for walking. This factor correlated with a fear of falling measured with the FES-I ($p < 0.01$).

4. Near-syncope

Near-syncope was characterized by a tendency to fall and episodes of near-syncope with short intensive attacks of vertigo requiring bed rest. The subjects could not differentiate the reason for their falls. Near-syncope syndrome correlated significantly with the critical time for control in open versus closed loop postural control ($p < 0.01$) and associated with falls in the logistic regression analysis ($OR = 1.5$, $p = 0.002$).

5.1.3 Neuro-otological/video-oculography results

Thirty-eight institutionally residing older adults continued to neuro-otological testing with VOG. Of the 38 subjects, 26 (68%) suffered from vertigo/dizziness and balance problems. From the 38 subjects studied, three subjects had cerebellar ataxia, one had undergone craniotomy after trauma and one had a cerebral shunt. Five subjects had Parkinson’s disease. In six subjects, visual problems caused impairment in voluntary eye movement tests due to disparity of gaze nystagmus (1), cataract (2), parafoveal fixation (1), hemianopsia (1) and/or strabismus (1). Due to frailty and/or dementia, complete positional and vestibular testing could not be carried out in five subjects.

Spontaneous nystagmus was studied from 34 subjects (Table 8). Five had spontaneous nystagmus and it was most commonly the vertical down-beating type (4 out of 5). Positioning testing for BPPV was studied in 31 subjects. Seventeen subjects had positional nystagmus. The presence of nystagmus in positioning testing was correlated with a sensation of vertigo ($r = 0.471$, $p = 0.007$) except in four subjects who had nystagmus but did not report any vertigo, and in three without nystagmus who reported moderate or severe vertigo. Three subjects had positional nystagmus in bilateral positions. Positional nystagmus was further classified either as being peripheral or central based on the other neuro-otological findings (vertical nystagmus, gaze deviation nystagmus) and case-histories of the CNS. Eight subjects were classified as having the central type of positional vertigo. Nine were classified as BPPV (representing the peripheral type of vertigo). Neither age nor gender correlated with
any of the neuro-otological variables. Poor mobility was correlated with positional nystagmus of the central type ($r = 0.457$, $p = 0.010$).

Table 8. Measurements and clinical assessment

<table>
<thead>
<tr>
<th>Test/Dysfunction</th>
<th>Pathological</th>
<th>Normal</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous Nystagmus</td>
<td>5</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>Dix-Hallpike (Positional Nystagmus)</td>
<td>17</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Dix-Hallpike (Vertigo)</td>
<td>16</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>Gaze in 20–30 degrees position (Nystagmus)</td>
<td>5</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Vestibulo-ocular Reflex (VOR) at 1 Hz</td>
<td>6</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>Head-shaking test (Nystagmus)</td>
<td>9</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>Head Thrust test (Re-fixation saccades)</td>
<td>10</td>
<td>23</td>
<td>33</td>
</tr>
<tr>
<td>Saccades</td>
<td>26</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Smooth Pursuit</td>
<td>17</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

Presbyequilibrium factor associations with vestibulo-ocular testing

In this smaller group for VOG-testing (n = 38), four factors were found to have common components of vertigo/dizziness and balance problems. Factors were further analyzed to find associations with the neuro-otological/VOG findings and falls.

1. Vestibular irritability

Subjects had vertigo/dizziness provoked by physical strain, often accompanied by nausea. Subjects experienced episodes of sudden instability and poor balance. Vestibular irritability correlated with BPPV findings in the neuro-otological testing ($r = 0.383$, $p = 0.035$).

2. Positional vertigo/dizziness

Subjects experienced postural imbalance that was provoked by positional changes. BPPV findings in neuro-otological testing correlated negatively with this category ($r = -0.279$, $p = 0.060$).
3. Frailty

Subjects had poor muscle strength and coordination, and they needed assistance for moving. Subjects preferred to use their hands to assist themselves when rising from a chair and used supporting devices for walking. They reported more continuous dizziness, associated with subjective feeling of falling. Frailty correlated with central positional nystagmus in the neuro-otological /VOG testing ($r = 0.469$, $p = 0.008$).

4. Autonomic vertigo/dizziness

Autonomic vertigo/dizziness was characterized by episodes of syncope, near-syncope or a floating sensation, which were all provoked by positional changes. This factor tended to correlate with falls ($r = 0.252$, $p = 0.067$).

5. Falls and posturography among community-dwelling older adults

5.2 History of falls

Occurred falls from the preceding three-month period were queried and 30 of the 96 community-dwelling participants had incurred a fall. The conditions under which the falls had occurred are shown in Figure 2. One subject had post-fall amnesia and became unconscious for a short time (eye witnessed). It led to a doctor evaluation, as was also the case in one other subject. In the remaining cases, the falls did not lead to any adverse health consequences. In 20 cases, the falls were eye-witnessed. Fallers were seen to have significantly greater FES-I scores ($t = 3.8$, $p < 0.001$) than non-fallers and had reduced QoL-scores in discomfort ($t = 3.02$, $p = 0.003$) and depression ($t = 2.10$, $p = 0.039$).
5.2.2 Posturography findings, symptoms and falls

Force platform posturography was carried out in 67 subjects. The critical time for controlling the open loop versus closed loop of posture differed significantly between fallers and non-fallers ($t = 2.32, p < 0.02$). The variable measuring zero crossing velocity showed a high rate of velocity change around the neutral position of stance, however significance between fallers and non-fallers was borderline ($t = 2.00, p = 0.05$). The critical time for control of the open loop versus closed loop control of posture had an OR for falls of 6.3 ($p < 0.001$) and zero crossing velocity value of 1.2 ($p < 0.001$) respectively.

In regression analysis, vertigo/dizziness attack intensity ($t = 4.44, p < 0.001$) had a statistically significant association with the time for control in open and closed loop control in the posturography.

The level of physical exercise queried in the otoneurological questionnaire was assimilated with postural stability measured with posturography. Even a moderate level of exercise improved postural stability and especially, the parameter measuring the critical time for control in open versus closed loop of posture ($p < 0.001$).
5.3 Fall prevention intervention study

Falls
Fifty-nine percent (39/72) of the institutionally residing older adults study group fell at least once. In total 140 falls were recorded in the three-year period (range 0–30 falls). In logistic regression analysis, only in habitual fallers (> 7 falls within the follow-up period) did the posturography measures correlate with a number in falls (number of low variability \( r = -0.466, p < 0.01 \), and zero crossing rate of velocity signal in AP-direction \( r = 0.278, p < 0.05 \)).

Effect of training on posturography and falls
After the three month training period all groups showed significant improvement on postural stability in posturography, however the results between the groups were not statistically significant. The posturographic results in the muscle force training group improved the most, followed by the self-training group and balance training group, but the differences were not statistically significant.

After training, the occurrence of “spiky” oscillations were reduced and the stationary fields of torque moment of the ankle increased providing better stability. In all groups their postural strategy was changed so that the subjects started to oscillate around a pre-determined attractor (neutral point) and tried to hold their posture without exceeding its stability ranges. They did however sway to the same extent as before commencing the training when measured by means of sway velocity and area of body sway.

Subjects who attended muscle force training and subjects who attended balance and muscle force training had fewer falls within the three years follow-up than those with self-administered training (Table 9). The difference between the groups was statistically significant (\( p = 0.02 \)).

Table 9. Falls in different training groups

<table>
<thead>
<tr>
<th>Falls measured during three years follow-up</th>
<th>Muscle training (n = 16)</th>
<th>Self-administered training (n = 19)</th>
<th>Muscle and balance training (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants who had fallen</td>
<td>7</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Participants with two or more falls</td>
<td>6</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Number of falls (range)</td>
<td>42 (1–21)</td>
<td>64 (1–30)</td>
<td>24 (1–8)</td>
</tr>
</tbody>
</table>
Effect on quality of life

At the beginning of the training the 15D-QoL scores were 0.8 (0.77–0.82), but this was reduced to 0.71 (0.71–0.73) after the training ended (paired Student’s t-test, p < 0.001) and was 0.73 (0.71–0.75) after six months from the beginning of training (p < 0.001) (Table 10).

Table 10. Quality of life in the beginning and after the training period

<table>
<thead>
<tr>
<th>Training Group</th>
<th>15D-QoL score (Standard Deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle training</td>
<td>0.82 (0.06)</td>
</tr>
<tr>
<td>Muscle and balance</td>
<td>0.81 (0.1)</td>
</tr>
<tr>
<td>Self-administered</td>
<td>0.77 (0.1)</td>
</tr>
<tr>
<td>Muscle training</td>
<td>0.71 (0.12)</td>
</tr>
<tr>
<td>Muscle and balance</td>
<td>0.73 (0.11)</td>
</tr>
<tr>
<td>Self-administered</td>
<td>0.71 (0.11)</td>
</tr>
<tr>
<td>Muscle training</td>
<td>0.71 (0.12)</td>
</tr>
<tr>
<td>Muscle and balance</td>
<td>0.75 (0.12)</td>
</tr>
<tr>
<td>Self-administered</td>
<td>0.73 (0.09)</td>
</tr>
</tbody>
</table>

When analyzing internal factors of the 15D-QoL instrument, the mobility rating at the beginning and after training showed no significant changes. However, vitality (p < 0.001) and usual activities (p < 0.05) scores lowered significantly after training had ended. No differences were found between the training groups.

After the training period had ended, the subjects felt more depressed (p < 0.05) and distressed (p < 0.001) than at the beginning of training. The depression scores returned to baseline levels after six months from commencing the training.
In this study, vertigo/dizziness and balance problems were observed in 44% of community-dwelling older adults rising up to 68% in those older adults residing in an institutional setting. Using factorial analysis to identify combining factors for symptoms for vertigo/dizziness and balance problems, four to six different diagnostic groups could be determined. Diagnose-related factors for the multi-symptomatic dizziness/vertigo and balance problems among older adults lead us to more targeted treatment and intervention. In both community-dwelling and institutionally residing groups quality of life was lower among subjects suffering from vertigo/dizziness and balance problems.

In posturography it was demonstrated that in aging, the postural confidence area becomes more limited and the oldest adults cannot compensate inadequate postural responses as younger adults. In neuro-otological/VOG assessment it was observed that a large proportion of the older adults living in institutional settings have a vestibular finding, the most common being nystagmus in Dix-Hallpike positional testing and pathological findings in saccades. However we could not present association with increased falls or lower quality of life among older adults with inner ear condition.

In this study it was demonstrated among institutionally residing oldest adults after three months of training, they could improve their postural stability and the amount of falls was decreased. Improving in postural stability and decreasing of falls was also observed with older adults suffering from lower MMSE scores. Among the trainees, the quality of life was reduced after the training had ended, in terms of distress, vitality and usual activities. We conclude that in residential homes, efforts should be made to increase guided muscle force training, but that training activities should be long-term, integrated with daily activities and consistent throughout the year.

Among community-dwelling older adults we could determine in factor analysis four groups with same defining factors for vertigo/dizziness and balance problems. Falls were reported among 30% of the community-dwelling older adults within the preceding three months and the subjects who had fallen had lower QoL-scores. Two variables in the posturography were in association with falls. Even a moderate level of exercise was associated with better performance in postural stability measurements.
Vertigo/dizziness and balance problems among older adults combine multiple symptoms and different underlying comorbidities that increase with aging. The term presbyequilibrium encompasses balance problems, postural instability and dizziness induced by aging.

6.1 Characteristics of presbyequilibrium

6.1.1 Presbyequilibrium in the older adults

In a longitudinal study, Jönsson et al., (2004) observed that the prevalence of vertigo and dizziness increases with age, ranging from about 30% at the age of 70 years to about 50% at the age of 85 years or more. These results are parallel with this study; presbyequilibrium was observed in 44% of those older adults living in the community, rising up to 68% in those living in an institutional setting. Belal and Glorig (1986) studied dizzy patients over the age of 65 years and dizziness could be further diagnosed in only 21% of cases. In the remaining 79%, the authors coined the term “primary disequilibrium of ageing”. In this study in the older adults living in an institution; with neuro-otological testing, a specific diagnosis for dizziness/vertigo could be found among 40% of the cases.

Deterioration of balance is an insidious process, starting in late middle age (Hytönen et al., 1993). Agrawal et al., (2012) demonstrated also that the semicircular canal and the otolith organs deteriorate with ageing. Most often, the older adults cope with this deterioration by using avoidance strategies, instead of re-challenging their balance. In this study in posturography it was demonstrated that in the institutionally residing older adults group there was a powerful limitation of the postural confidence area. We performed a factor analysis according to the symptoms to identify the internal associations of presbyequilibrium. In addition, the associations of presbyequilibrium with the number of falls, the fear of falling neuro-otological/VOG tests, mortality and with the quality of life were determined. The components of presbyequilibrium were characterized by the following complaints: 1. Feeling of rotation. 2. Feeling of floating. 3. Tendency to fall. 4. Postural instability when moving. 5. Sudden drops of balance without losing consciousness. Symptoms-related factors queried were duration spells, occurrence and intensity of the dizzy spells. Symptoms could occur either in isolation or in combination.
Factor 1. Vestibular failure/irritability

Vestibular failure/irritability was found in both institutionally residing and community-dwelling older adults. Dizziness was characterized by episodic spells of rotatory or floating sensation, provoked by physical strain or activity and accompanied with nausea. Within the vestibulo-ocular testing group it correlated with BPPV-findings. In the community-dwelling older adults, vestibular failure/irritability was associated with falls in the regression analysis. Fife and Baloh (1993) demonstrated reduced vestibular function among older adults with undiagnosed disequilibrium with increased sway velocity. They concluded that quantitative measurement of vestibular function should be considered in older adults complaining of disequilibrium. Lawson et al., (2005) demonstrated how older adults with BPPV do not necessarily report their associated complaints. Hirvonen et al., (1998) observed in head autorotation tests that in the older adults, the gain in VOR was elevated at high frequencies. These compensatory efforts may be due to a deterioration of the semicircular canal and/or otolith dysfunction by age. Older adults suffering from vestibular failure need medical and vestibulo-ocular examination for diagnosing the underlying pathophysiology, which could entail central and/or peripheral failure.

Factor 2. Positional presbyequilibrium

Positional presbyequilibrium was prominent with those older adults living in an institution. Subjects suffered from frequent episodes of postural instability, which was provoked by positional changes and physical strain. It correlated with reduced physical performance and in the vestibulo-ocular testing group it correlated negatively with BPPV and was associated with falls in the regression analysis. In a study by Colledge et al., (1994, II) 27 % of 900 randomly selected older adults suffered from dizziness. Dizziness was most commonly provoked by postural change as well as head and neck movement. Ensrud et al., (1992) studied postural dizziness among 9704 older women. Postural hypotension and postural dizziness were common findings, noted in 14 % and 19 % of subjects, respectively. Postural dizziness was strongly associated with a history of falling, a history of syncope and impaired functional status.

Factor 3. Frail presbyequilibrium

Frail presbyequilibrium could be found in both institutionally residing and community-dwelling older adults. Vertigo was more continuous and described as postural instability and the feeling of falling. Subjects had poor muscle strength.
and preferred to use supporting devices for walking. Speechley and Tinetti (1991) studied 336 community-dwelling older adults who were divided into Frail, Vigorous or Transition groups based on observed patterns of their demographic, physical, and psychological variables. The incidence of falling in one year was highest in the Frail group (52 %) and lowest in the Vigorous group (17 %). However, 22 % (5/23) of falls by vigorous subjects resulted a serious injury, as opposed to 6 % (5/89) of falls by frail subjects. Similar results could be found in our study group where it was discovered that institutionally residing frail older adults needed more assistance in their daily movements and had more falls.

Within the institutionally residing older adults, frail presbyequilibrium correlated with reduced ability in usual activities, reduced mobility, poor vision, reduced mental functions and habitual falls. Within the community-dwelling older adults it correlated with an increased fear of falling, thus supporting the results of Delbaere et al., (2004) who studied 225 community-living older adults aged between 61 and 92 years of age. They concluded that fear-related avoidance of activities may have negative effects on physical abilities and also be possibly predictive of future falls.

Chen et al., (2014) defined possible interventions for the frailty syndrome being exercise programs and nutritional interventions. Campbell and Szoeke (2009) concluded that pharmacological treatments such as vitamin D has favorable pharmacological and safety profiles, but clinical utility in the prevention and treatment of frailty has yet to be investigated. In parallel with exercise programs Chen et al., (2014) conducted that a comprehensive geriatric interdisciplinary assessment is the key for interventions in the frailty syndrome. The interdisciplinary assessment consists the expertise of geriatrician, a gerontologically trained nurse, a social worker, a pharmacist and both occupational and physical therapists.

Factor 4. Autonomic Vertigo/Near-Syncope

Autonomic vertigo was prevalent in both institutionally residing and community-dwelling older adults. It is characterized as episodes of syncope or near syncope, or an intensive episode of vertigo that required bed rest. Vertigo episodes were described as a floating sensation that was provoked by positional changes. Subjects also suffered from a sensation of falling.

Staab et al., (2002) introduced the term autonomic dizziness, where autonomic challenges (such as voluntary hyperventilation, tilt-table test and sodium lactate infusions) provoked dizziness. Autonomic vertigo/near-syncope has multiple components similar to NCS. Ross and Parry (2008) studied 418 subjects with NCS (median age 60 years) and 70 % of them presented with syncope.
Rafanelli et al., (2014) studied 873 syncope patients (aged 66.5 ± 18 years) with tilt testing, carotid sinus massage and both supine and upright blood pressure measurements (neuro-autonomic evaluation). Patients over 65 years of age had a higher rate of complex diagnosis. The researchers concluded that a neuro-autonomic evaluation is useful in older patients with unexplained syncope after their initial evaluation.

Factor 5. Movement intolerance

Movement intolerance was prevalent in both institutionally residing and community-dwelling older adults. It is characterized as the constant feeling of dizziness, often accompanied with nausea and instability. Subjects suffered from sudden slips or trips but without the feeling of falling.

The characteristics of movement intolerance are similar to Mal de Debarquement syndrome (Clark et al., 2013) in that the older adults do not properly adapt to a change in the vestibular function. It may involve impairment in the postural memory or in the pathways controlling vestibular memory as we observed an association between the MMSE scores and the movement intolerance factor. Subjects suffering from the movement intolerance are challenging for physicians and therefore require a differential diagnosis consultation from an otolaryngologist and/or neurologist, and possible neuro-imaging.

6.2 Results of neuro-otological/VOG assessment

The presence of spontaneous nystagmus indicates an asymmetry of vestibular influx that occurs commonly in non-compensated vestibular function loss or in CNS processes affecting the VOR within the cerebellar-brain stem. Spontaneous nystagmus was observed in 15 % of the institutionally residing subjects. Spontaneous nystagmus was most commonly of the vertical down-beating type (4 out of 5) that concurs with the earlier findings of Baloh (1998). Davalos-Bichara and Agrawal (2014) observed a high prevalence of abnormalities (44 %) in clinical vestibular testing in healthy older adults, although any self-perceived dizziness was low. They suggested that older adults should be tested with a head rotation test to reveal the finer degradations of vestibular function, as in older individuals the levels of vestibular loss are associated with functional impairment.

As BPPV has been reported to occur frequently in the older adults, the Dix-Hallpike positioning test is most useful to be carried out to reveal a specific vestibular pathology. In 100 consecutive patients referred to a geriatric day-care unit, 9 % had
BPPV in a study by Oghalai et al., 2000. Commonly, positioning tests are used to reveal BPPV in the posterior semicircular canal. A test for BPPV in the lateral semicircular canal is also often carried out. The test is positive if dizziness is provoked together with nystagmus characteristic for the semicircular canal in question.

In this study, nystagmus in positional testing occurred in 55 % (17/31) of the institutionally residing older adults. Three subjects had positional nystagmus in bilateral positions. Eight subjects were classified as having the central type of positional vertigo. Nine were classified as BPPV (representing the peripheral type of vertigo). Vestibular malfunction among older adults has also been demonstrated by other researchers (Sloane et al., 1989 II; Nadol and Schuknecht, 1989; Kristinsdottir et al., 2000). Conradsson et al., (2013) observed that the vestibular complaints did not always accompany the nystagmus observed in the positioning test. The older adults could have a vigorous nystagmus without vertigo or dizziness, or alternatively experience symptoms without any nystagmus. In older adults with BPPV Ganança et al., (2010) discovered that falls could be prevented by the particle repositioning maneuver.

Lawson et al., (2005) conducted a study with older adults suffering from BPPV which was confirmed with Dix-Hallpike positional test. Fifty-three percent of the older adults with BPPV were referred to a fall-and-syncope-unit instead of to ENT. The subjects referred to the fall-and-syncope-unit were older and had experienced dizzy symptoms for a longer period of time. They also described their symptoms as more than one type of dizziness and not with symptoms classical of BPPV. Oghalai et al., (2000) performed a cross-sectional study with community-dwelling older adults to define the prevalence of unrecognized BPPV. In multi-variate analysis they demonstrated that the presence of a spinning sensation and the absence of a sensation of light-headedness predicted the presence of unrecognized BPPV. The positive predictive value was 71 %. BPPV was commonly associated with nausea and 9 % of their study cohort was found to have unrecognized BPPV. These studies confirm our findings that with older adults, BPPV can be challenging to diagnose since the symptoms and findings are not convergent with the working-age population. Tests for BPPV should be assessed to all older adults with symptoms of presbyequilibrium since the symptoms in the older adults do not always lead to clear diagnosis.

The specificity of the head thrust test for identifying lateral semicircular canal pathology for patients with unilateral vestibular hypofunction is high (95–100 %). Although for patients with non-surgically induced unilateral hypofunction, the head thrust test has a sensitivity of 34 % to 39 % and a specificity of 95 % to 100 % (Beynon et al., 1998). In the present study positive head thrust test was detected in 30 % of the institutionally residing older adults.
Horizontal head-shaking nystagmus (HSN) is clinically significant and useful tool in evaluating unilateral vestibular hypofunction (Takahashi et al., 1990; Jacobson et al., 1990). Excluding additional central vestibular imbalance or Meniere’s disease, the direction of horizontal HSN is highly significant in indicating the side of the lesion, with the fast phase beating toward the intact side.Peripheral vestibular hypofunction as well as a central asymmetry of the vestibular velocity storage mechanism can each separately or in combination produce horizontal HSN, therefore further otoneurological testing is necessary to diagnose subjects’ condition. In this study HSN was detected in 27% of the institutionally residing older adults.

6.3 Posturography outcome in community-dwelling older adults

Deandrea et al., (2010) showed that gait and balance impairments are the most serious risk factors for falls in the community-dwelling older adults, seconded only by a history of previous falls. Gait and balance impairments were deemed to carry respectively around two- and three-fold increased risk for falling. This concurs with the findings of the present study. Era et al., (2006) demonstrated by performing posturography testing in 7979 subjects, that a decline in balance functions occurs with advancing age, accelerating from about 60 years upwards. Maki et al., (1999) demonstrated on posturography a reduction of rapid stepping reactions with ageing. Older adults were much more likely to take multiple steps or use arm reactions to regain equilibrium than younger adults. They also showed that in the posturography measurements, plantar facilitation reduced the incidence of “extra” limb movements, beyond the initial step during forward-step reactions in older adults. Younger subjects were better able to recover their balance without stepping when falling backward.

Piirtola and Era, (2006) conducted a review on the predictivity of the posturography measurements on falls. Nine studies were included. For the various parameters derived on the basis of force platform data, the mean speed of the medio-lateral movement of the center of pressure (COP) during normal standing with the eyes open and closed, the mean amplitude of the ML movement of the COP with the eyes open and closed, and the root-mean-square value of the ML displacement of the COP were the indicators that showed significant associations with future falls. Measures related to dynamic posturography were not predictive of falls. Among community-dwelling older adults in this study, the conventional posturography measurements did not prove to be useful in predicting fallers.

In this study two variables were found to have associations with falls within the last three months. The critical time for controlling the open loop versus closed loop of posture and the variable measuring zero crossing rate velocity. In the logistic reg-
ression analysis, falls correlated with these two variables. Especially the parameter measuring the critical time for control in open versus closed loop of posture improved significantly with even a moderate level of exercise (more than twice a week).

6.4 Training intervention in the institutionally residing older adults

6.4.1 Training and effect on falls

When comparing the fall rates between guided balance training combined with muscle force training and guided muscle force training with self-administered training in institutionally residing older adults, the outcome of fall rates differed between the training groups; guided balance and muscle training was clearly more effective than self-training in fall prevention. Rubenstein et al., (1994) identified the underlying risk factors for falls and injuries among the older adults. These were lower-extremity muscle weakness, gait and balance instability, poor vision, cognitive and functional impairment and both sedative and psychoactive medications.

Lower-extremity muscle weakness increases with age and especially among those institutionally residing older adults (Lexell, 1995; Aniansson et al., 1986). Several studies favor the prevention of falls in the institutionally residing older adults by using physical therapy (Becker et al., 2003; Sihvonen et al., 2004). Common to all these studies was that they used balance training and walking exercises. In contrast, several other studies were unable to show that walking and endurance training could prevent falls in institutionally residing older adults (McMurdo, 2000; Shimada et al., 2004).

Residents with moderate or severe dementia could perform exercises in a five person group under the supervision of a physiotherapist. The MMSE-scores neither correlated with the level of falls nor the outcomes of posturography. In the Finnish Alzheimer Disease Exercise Trial (Pitkälä et al., 2013) among community-dwelling older adults with a spousal care-giver, after one year of training, improvement in physical functioning occurred without increasing the total cost of health and social service provision. In the control group without any exercise, there were more falls when compared to the exercise groups. This confirms our suggestion that demented older adults cannot only fully participate in exercise interventions, but can also benefit from them.

6.4.2 Results on posturography measurements

Posturography revealed an improvement in postural stability and balance control strategy. When inspecting the effect of training on postural stability, all groups
showed significant improvements. The muscle force training groups tended to improve the most, followed by the self-training group and then the balance training group, although the differences were not statistically significant. We have previously indicated that body sway is a random phenomenon in the older adults (Rasku et al., 2012, II); this phenomenon contrasts with younger residents in whom body sway is predictive and seems to oscillate around an attractor. After three months of training we were able to show that participants regained the strategy to sway around an attractor. An improvement in postural stability was not observed in traditional measures such as the velocity of body sway or sway area; however, an improvement was noted in the strategy with a move towards diminishing periods of random body oscillations. Muscle force training is especially useful to prevent slips and falls but also improves the postural stability during quiet stance.

Hytönen et al., (1993) showed that visual influx has a crucial role in the postural control of the older adults, whereas the proprioception and plantar skin pressoreceptor influxes are strongly reduced, undermining their role in controlling the body sway. This reduction of proprioception and exteroception also affects the detection of torque in the ankle joint which explains why the zero crossing velocity was increased. Pyykkö et al., (1990) studied the oldest adults group with posturography and found out that when compared with a group of working age subjects, the older adults had significantly higher sway velocities. Visual deprivation had a significant effect on postural stability, to which visual influx contributed about 50 %.

6.4.3 Results on quality of life

Effects of interventions on quality of life have been evaluated using different general health related measures (Vaapio et al., 2009). Bicket et al., (2010) demonstrated that physical surroundings influence on the quality of life and neuropsychiatric symptoms in assisted-living residents. The general health-related 15D-QoL-instrument for institutionally residing older adults includes physical dimensions, psychological dimensions and social dimensions (Sintonen, 2001). We demonstrated using the 15D-QoL-instrument that the psychological and physical components (vitality, usual activities, depression and distress) were altered after the rehabilitation had ended. Evidence emerging within the past few decades suggests that the psychosocial factors (e.g. emotional states such as depression, reduced mental function and behavioral dispositions) can directly influence the management of daily activities (Vaapio et al., 2009).

In this study in the rehabilitation intervention, the 15D-QoL scores reduced after the three month training period had ended. In a randomized study by Clemson et al.,
(2012) among older adults aged 70 years or older, in that although balance improved and the fall rate was reduced, the EQ-5D instrument showed no increase in quality of life score after a 12 months follow-up time.

In a younger group of older adults with a mean age of 67 years, Kuptniratsaikul et al., (2011) undertook a fall intervention among community-dwelling older adults. One hundred forty-six subjects did simple balance exercises in their own home. Balance tests and quality of life were evaluated. At the end of the training period, quality of life increased significantly. Factors affecting falling were in compliance with exercise, however in this study the subjects were about 20 years younger when compared to our intervention group.

In our study the QoL was measured before training, after the training had ended and six months after the beginning of the training. The decreasing of the QoL was the same in each group even though the individually training group stayed at their wards and their exercise program was not progressive. In such studies the QoL measurements should be scheduled right before commencing the training, just before the training has ended and the confounding factors such as the time of year should be the same during the analysis. Therefore also measurements after 12 months should be included in rehabilitation intervention studies. In future studies also open opinions from the subjects are recommended, this can be done with structured interviews.

6.5 Comment on methods

6.5.1 Study population and design

Of nearly 900 older adults living in Koukkuniemi home, 156 older adults were included to the intervention group. However, only half of the subjects could attend to the intervention or changed their minds about the study. Forty-nine participants continued to the end of the fall intervention which lasted three months, from which 38 subjects could/wanted to continue to neuro-otological/VOG testing. The findings may reflect a somewhat better health situation compared to institutionally residing older adults in general, and this may limit the generalizability of the findings. The study among the older adults (n = 96) living in the community setting was carried out among members of the Tampere Pensioner Association. The participants were relatively young older adults, socially active and participated in the study voluntarily as promoted by the local pensioner organization, thus representing the “active” older adults group.
6.5.2 Data collection and assessment

For investigating the study subjects’ symptoms and for clarifying medication and medical history we used the otoneurological questionnaire. To complete the questionnaire among the demented residents living in an institution, we used their personal nurses as proxies to obtain the current symptoms. The medication history and the ICD-diagnoses (International Classification of Diseases) were verified from the medical records.

To characterize/diagnose subjects’ presbyequilibrium, the symptoms were broken down into more detail as rotatory vertigo, dizziness, movement instability, fear of falling, sudden loss of balance, light-headedness, floating sensation and/or black-out. These symptoms may be difficult to recount by the proxies, thus leaving some uncertainty in the case history concerning presbyequilibrium among the demented older adults.

The neuro-otological/VOG testing was conducted in a small group of the oldest adults. Tests included spontaneous nystagmus, gaze deviation, VOR-tests, HSN, head thrust, smooth pursuits, saccades and Dix-Hallpike. Considering the smallness of the selected group, the test results can delineate only those major faults in oculomotor and vestibular testing. Some subtle changes in the vestibular system thus remain undetected. Therefore the incidence of vestibular faults is probably greater in reality than demonstrated in the present study. In neuro-otological testing the caloric test is commonly used in assessing vertigo in unilateral cases, although it seems not to be useful in the clinical assessment of older adults, as in bilateral hypofunction the vestibular responses are often symmetric, and the older adults quite often feel nauseated and may vomit. Further, the caloric test does not describe the functional aspects of the vestibular system. Rohrmayer et al., (2013) compared the outcome of bedside tests consisting of spontaneous nystagmus, HSN and the head impulse test with caloric testing. The bedside tests had a sensitivity of 64 % with a specificity of 85 %. They concluded that bedside tests provided a good screening tool that quickly and reliably excluded unilateral weakness, and in particular, any pronounced canal paresis on caloric testing. Various bedside tests were chosen in this study to characterize presbyequilibrium among older adults. Routinely clinical tests commence with the recording of spontaneous nystagmus and gaze deviation nystagmus continuing with saccades and smooth pursuits. Other tests that are recommended for clinical testing (Brandt 2003; Fetter 2000; Brandt and Strupp 2005; Goebel 2001) are the Dix-Hallpike test, head shaking test, head thrust test and the clinical evaluation of VOR. In the older adults, the eye lids may hang over the pupils and can hamper any computerized analysis of VOG. Based on these tests however, we found vestibular abnormalities in 17–76 % of the older adults living in the residential setting depending
on the test conducted. Diagnosing BPPV, the use of VOG, either with Frenzel’s or Bartel’s glasses is recommended, as sometimes fine nystagmus may be suppressed if the patient is able to fixate. In this test there is also a need of some experience to recognize nystagmus, together with knowledge of which nystagmus type is expected from BPPV referring to a specific semicircular canal. Not all position provoked nystagmus is due to BPPV (Buettner et al., 1999). Additionally, in the frail older adults’ violent neck bending may lead to fainting and cerebrovascular complications in the Epley maneuver (Hilton and Pinder, 2012).

We used a custom-made force platform posturography for oldest adults living in an institution and for community-dwelling older pensioners. In posturography, the center point of force has commonly been used to characterize the subject’s ability to control their posture. The conventional parameters used have failed to distinguish fallers from non-fallers in geriatric facilities. There are many possible explanations for this, including a shortage of optimal reference persons; that “near falls” are handled as non-falls due to the stochastic nature of falls; and also the shortage of descriptive parameters used in evaluation. In spite of these shortcomings however, posturography is a useful instrument in describing the outcomes of rehabilitation because it detects in details several different components which are proven to be in direct correlation in the level postural stability. Also posturography measurements are easy to conduct even with subjects with moderate level of dementia.

The otoneurological questionnaire, the health-related quality of life and the FES-I questionnaire were interviewed by one researcher (ET) among the institutionally residing older adults. When necessary, the subjects’ interviews were confirmed or augmented by interviews with their personal nurses who served as proxies as well as the MMSE-testing was conducted with the help of personal nurses. In our opinion an interviewed questionnaire consisting medical symptoms even among moderately demented older adults can be reliable when interviewed by same professional in one study group.

Medications effect on falls is well-acknowledged and studied risk factor. In this study we did not examine polypharmacies associations with presbyequilibrium, falls and quality of life. In a review by Gillespie et al., (2012) gradual withdrawal of psychotropic medication reduced rate of falls, but not the risk of falling. A prescribed modification program by primary care physicians significantly reduced the risk of falling. In a study by Lampela et al., (2013) a Comprehensive Geriatric Assessment (CGA) including evaluation of the adequacy of the medication decreased orthostatic hypotension among 1000 older adults over the age of 75 years. Due to wide variations of variables and limitation of the study design, medication evaluation could
not be part of the assessment. However it is a challenging topic for future studies in this population.

6.5.3 Statistical methods

Data collected with the otoneurological questionnaire was transferred to SPSS statistical analysis software (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.). Principal component analysis was used to find common indicators for groups of factors; with this method we formed the presbyequilibrium factor groups. Associations with posturographic tests, neuro-otological testing, fear of falling, mortality and quality of life were further analyzed.

When comparing groups in intervention studies power calculations are needed in order to determine valid group sizes for each intervention. When conducting interventions with years of follow-up time among institutionally residing older adults, high mortality should be taken in consideration when designing the group sizes. Therefore power calculations are needed.

6.6 Clinical implications

Using a structured questionnaire to gain full clinical symptoms and history we could determine several therapeutically meaningful groups of presbyequilibrium by using factorial analysis. These factors lead the general practitioner to refer older patients to correct consultations (e.g. ENT, internist, geriatran, and physiotherapist). Factors were further analyzed in how they associated with neuro-otological examinations/VOG, falls, QoL, fear of falling, mortality and posturography results. Neuro-otological/VOG work-up and posturography are too time and resource demanding in everyday general practitioners evaluations. However, in such characterization and intervention studies neuro-otological evaluation/VOG and posturography work adequately and therefore are advisable. Multi-expertise approach in diagnosing this very challenging combination of symptoms require new approach techniques, diagnostic tools and resources. In practice, collaborative presbyequilibrium clinics could help detect those older adults with a higher risk of falling and direct them to proper rehabilitation services.

Subjects who attended muscle force training and subjects who attended balance and muscle force training tended to have fewer falls within the three years follow-up than those with self-administered training. Based on our study guided exercise rehabilitations is more effective than self-administered. Exercises should contain balance training, however the rehabilitation should be moderate in the beginning and
continue in upward tendency. Also training should be long-term, constant and part of the weekly schedule. In our group the QoL points were lower after the training had ended, however we do not conclude that training lowers quality of life. More studies are needed where high variety of confounding factors (e.g. time of year) in such of population is taken in consideration.

Also we suggest more resources being directed to presbyequilibrium and fall studies in Finland. We need larger intervention studies with multi-factorial approach including medication review, balance and muscle training, external limitations evaluation (such as safe apartment design, shoes, surfaces) and presbyequilibrium specialists’ assessment on possible treatable conditions.
7 CONCLUSION

The aim of the present study was to define presbyequilibrium among community-dwelling and institutionally residing older adults by means of otoneurological interview, neuro-otological/VOG assessment and force-platform posturography. These outcomes were further evaluated with their associations with falls and quality of life. We also evaluated the effectiveness of a three-month exercise program with falls, quality of life and balance among a group of oldest adults in an institutional setting.

1. Among institutionally residing older adults incidence of presbyequilibrium was 68%. Presbyequilibrium was divided into six diagnostic groups using factor analysis. From these factors frailty and autonomic vertigo correlated with falls and reduced quality of life.

2. With vestibulo-ocular assessment 40% of the presbyequilibrium cases could be further diagnosed into either peripheral inner ear or central nervous system condition.

3. In the guided balance and muscle training intervention, institutionally residing older adults reduced their number of falls when compared to self-administered training. Participants with dementia could undertake training program in groups.

4. Among the community-dwelling older adults, prevalence of presbyequilibrium was observed in 44% and falls in 31%. The critical time for control of the open loop versus closed loop control of posture and zero crossing velocity value predicted falls in the posturography measurements. Even a moderate level of exercise was associated with improved postural stability and reduced falls.
This study was carried out in collaboration with the Department of Otorhinolaryngology at Tampere University Hospital, the Department of Computer Sciences at Tampere University, and the Koukkuniemi Nursing Home in Tampere during 2004–2009. The study was supported by the Pirkanmaa Cultural and Science Foundation, EU PROFANE (Prevention of Falls Network Europe), Uulo Arhio Foundation and the Finnish otorhinolaryngology research foundation.

I am deeply grateful to the Koukkuniemi nursing staff, the Department of Physiotherapy and Dr. Jussi Ripsaluoma for providing a highly motivating and supportive environment for this study. Especially I would like to thank physiotherapists Päivi Moisio-Vilenius and Erja Mäkelä for designing our intervention program and motivating me with their enthusiasm.

I am greatly indebted to my supervisor Professor Markus Rautiainen who has encouraged me and guided me in this demanding project.

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I wish to thank my reviewers Timo Hirvonen and Eija Lönroos who offered many insightful and constructive comments. Jyrki Rasku and Esko Toppila – your expertise and knowledge in posturographic measurements and data analysis was indispensables.

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My father Antti and my parents-in-law Urpo and Riitta – you keep my feet on the ground with your strong but warm guidance. I especially wish to thank my father Antti, for letting me be myself and warmly supporting me in my decisions.
For my own grandmother Irja and my grandparents-in-law; Eino, Alli and Klaudia, you are the essence of this work and my true inspiration.
This book is dedicated to my husband Olli and my daughter Ella.

*Helsinki, July 2015*

Eeva Tuunainen
9 APPENDICIES

Appendix A

Otoneurologinen kysely

Kaikki vastaukset ovat luottamuksellisia ja kuuluvat sairaskertomuksiin liittyvän tietosuojan alaisuuuteen. Tutkimuksen kannalta on tärkeää, että vastaaisitte seuraaviin kysymyksiin huolettaisesti ja pyrkisitte vastaamaan kaikkiin kysymyksiin.

Henkilötiedot

1. Henkilötunnus

2. Nimi

3. Osoite

4. Puhelinnumero

5. Sukupuoli:
   Naisten
   Miehen

Olkaa hyvä ja merkitä rasti kysymyksen sen vastausvaihtoehdon kohdalle, joka kuvaa parhaiten terveydentilaanne.

Vastatkaa oireisiin liittyviin kysymyksiin sen mukaan, minkälaisia esiintyvät oireet yleisimmin ovat. Jos teillä ei nykyisin esiinny kyseistä oireetta, vastatkaa siihen liittyviin kysymyksiin sen mukaan, mikä tilanne oli oireiden esiintyessä.

6. Mitä oireita teillä esiintyy? (vállitkaa yksi tai useampi vaihtoehto)
   huimautus
   liikkumishäiriöt
   kuulonlännen
   korvien soiminen
   päähässä

Oireiden alku

7. Jos teillä on nyt tai on aikaisemmin ollut huimautusta, kuulonlännusta tai korvien soimista, niin millä seuraavista oireista sairauteen aiheutti?
   (vállitkaa yksi tai useampi vaihtoehto)
   huimautus
   kuulonlännem
   huumina
   peineen tunne korvassa
   liikkumishäiriöt

8. Kuinka vanha oltte, kun ensimmäiset oireet alkoivat?

Mikäli teillä ei ole huimautusta, voitte siirtyä kysymykseen 21 koskien liikuntakykyä.
9. Mikäli teillä on nyt tai on ollut aikaisemmin huimauta ja kuulonlennusta, niin oliko huimauksen ja kuulonalennuksen ilmenemisen välillä aikaeroa? *(valitakaa yksi vaihtoehto)*

<table>
<thead>
<tr>
<th>1 = alkoivat samanaikaisesti</th>
<th>2 = aile vuosi</th>
<th>3 = 1 - 4 vuotta</th>
<th>4 = 5 - 16 vuotta</th>
<th>5 = enemmän kuin 10 vuotta</th>
</tr>
</thead>
</table>

**Huimaus**

Kohtauksittaisella huimauksella tarkoitetaan ohimenevää huimauksen tunnetta, joka huimaavien kohtausten välillä on vähäoireinen tai oireeton.

Jatkuva huimaus tarkoittaa jatkuvia liikehäröitä tai jatkuvaa huimauksen tunnetta.

10. Onko teillä seuraavia oireita? *(valitakaa yksi tai useampi vaihtoehto)*

<table>
<thead>
<tr>
<th>pyörinnisen tunne</th>
<th>keihälyn tunne</th>
<th>taipumus kaatua</th>
<th>epävarmuus liikkuessa</th>
<th>tajunnan menetys</th>
</tr>
</thead>
</table>

11. Kuinka paljon aikaa on ensimmäisistä oireista? *(valitakaa yksi vaihtoehto)*

<table>
<thead>
<tr>
<th>1 = aile kuukausi</th>
<th>2 = aile vuosi</th>
<th>3 = 1 - 4 vuotta</th>
<th>4 = 5 - 10 vuotta</th>
<th>5 = enemmän kuin 10 vuotta</th>
</tr>
</thead>
</table>

12. Millaista huimauksenne on?

<table>
<thead>
<tr>
<th>1 = jatkuvaa</th>
<th>2 = kohtauksittaa</th>
<th>3 = molempia</th>
</tr>
</thead>
</table>

Mikäli huimauksenne on jatkuvaa, voitte siirtyä kysymykseen 18.

13. Kuinka usein voimakkaampia huimaukskohtauksia esiintyy?

<table>
<thead>
<tr>
<th>1 = vähemmän kuin kerran vuodessa</th>
<th>2 = vähemmän kuin kerran kuukaudessa</th>
<th>3 = kuukausittain</th>
<th>4 = viikottain</th>
<th>5 = päiviittäin</th>
</tr>
</thead>
</table>

14. Jos huimauksenne on kohtauksittaa, niin kuinka kauan voimakkaampi huimaukskohtaus kestää?

<table>
<thead>
<tr>
<th>1 = aile 1 min</th>
<th>2 = 1 min - 20 min</th>
<th>3 = 20 min - 4 tuntia</th>
<th>4 = 4 tuntia - 24 tuntia</th>
<th>5 = yli vuorokauden</th>
</tr>
</thead>
</table>

15. Kuinka voimakas huimaukskohtauksenne on yleensä?

<table>
<thead>
<tr>
<th>1 = erittäin lievä (ei vaikuta askareisin laikkaan)</th>
<th>2 = heikko (vaikuttaa, mutta voi jatkaa työtään normaalisti)</th>
<th>3 = kohtalainen (joutuu koskettämään työn)</th>
<th>4 = voimakas (joutuu leipäämään)</th>
<th>5 = erittäin voimakas (vaikuttaa levosta huomiota)</th>
</tr>
</thead>
</table>

16. Liittykö huimaukskohtauksiinne paahoinvointia tai oksentelua?

<table>
<thead>
<tr>
<th>0 = ei liity</th>
<th>1 = heikkoa</th>
<th>2 = kohtalaisia</th>
<th>3 = voimakasta</th>
<th>4 = erittäin voimakasta oksentelua</th>
</tr>
</thead>
</table>
17. Esiintyykö telliä äkillisiä voimakkaita sekunjämin - parin kestäviä huimauksia (horjahduksia)?

0 = ei esiinny 1 = satunnaisesti 2 = harvemmin kuin kerran kuukaudessa 3 = kuukausittain 4 = viikoltaan

18. Aiheuttaavatko asennon muutokset huimausta?

0 = eivät aiheuta 1 = heikosti 2 = kohtalaisesti 3 = voimakkasti 4 = erittäin voimakkasti (kaatu)

19. Aiheuttaako paineen vaihtelu (esim. lentäminen, sukeltaminen, puhaltaaminen tai niistäminen) huimausta tai tasapainovahkeuksia?

0 = ei aiheuta 1 = heikosti 2 = kohtalaisesti 3 = voimakkasti 4 = erittäin voimakkasti (kaatu)

20. Aiheuttaako fyysinen rasitus (esim. painon nosto) huimausta tai tasapainovahkeuksia?

0 = ei aiheuta 1 = heikosti 2 = kohtalaisesti 3 = voimakkasti 4 = erittäin voimakkasti (kaatu)

Liikuntakyky

21. Liikkuminen

0 = pystyn liikkumaan normaalisti 1 = pystyn liikkumaan pienin vaikeuksin 2 = pystyn liikkumaan huomattavain vaikeuksin 3 = pystyn liikkumaan vain vähän 4 = en pysty liikkumaan

22. Onko telliä tasapainovahkeuksia tai liikevaikeuksia (huimauskohtausten ulkopuolella)?

0 = ei ole 1 = satunnaisesti 2 = harvemmin kuin kerran viikossa 3 = viikoltaan 4 = jatkuvasti

23. Jos telliä on jatkuvia tasapainovahiriöitä (huimauskohtausten ulkopuolella), kuinka voimakkaina koette ne?

0 = ei lainkaan haltaa 1 = heikkoina 2 = kohtalaisina 3 = voimakkaina 4 = erittäin voimakkaina, kaatu

24. Pystynousemaan tuollalta

0 = normaalisti ilman käälä 1 = ajottain tukea ottaen 2 = aina tukea ottaen 3 = toisen avustamana lainkaan 4 = en pystyousemaan lainkaan

Kuulonalanema

25. Onko kuulonne alentunut sairautenne vuoksi?

0 = ei 1 = oikeassa korvassa 2 = vasemmatsa korvassa 3 = molemmissa korvissa
Mikäli teillä ei ole kuulonalenemaa, voitte siirtyä kysymykseen 29 koskien korvien soimista.

26. Mikäli koette kuulonne alentuneeksi, niin paljonko aikaa on kulunut sen alkamisesta?

1 = alle kuukausi  
2 = alle vuosi  
3 = 1 - 4 vuotta  
4 = 5 - 10 vuotta  
5 = enemmän kuin 10 vuotta

27. Vaihteleeko kuulonne aste huimauskohtauksien aikana?

0 = ei  
1 = kyllä

28. Kuinka kuulonalenemanne on alkanut?

1 = aikaisempi (muutaman vuoden aikana)  
2 = muutaman vuoden aikana  
3 = usean vuoden aikana

Korvien soiminen ja ääniylhärkkyys

Korvien soimisella tarkoitetaan korvassa tai päässä esiintyviä erilaisia ääniä, kuten sointia, huminaa, pulssin tunnetta jne. Ei tinnitusta.

Ääniylhärkkyys tarkoittaa kovien äänen aiheuttamaa kipua korvassa tai niiden aiheuttamaa hyvin lujana.

29. Kumpi korvanne soi?

0 = ei korvien sointa  
1 = oikea korva  
2 = vasen korva  
3 = molemmat korvat  
4 = soiminen on koko päällä

Mikäli teillä ei ole korvien soimista, voitte siirtyä kysymykseen 33.

30. Mikäli teidän korvanne soivat, niin paljonko aikaa on kulunut soimisoireiden alkamisesta?

1 = alle kuukausi  
2 = alle vuosi  
3 = 1 - 4 vuotta  
4 = 5 - 10 vuotta  
5 = enemmän kuin 10 vuotta

31. Minkä verran korvien soiminen haittaa elämää?

0 = ei haluttaa (ei vaikuta lainkaan toimintoihin)  
1 = heikkoa (pystyy normaaliin toimintaan)  
2 = kohtalaita (vaikuttaa, mutta pystyy normaaliin elämään)  
3 = voimakasta (jotkuvat keskeyttämään toimintaa)  
4 = erittäin voimakasta (jatkuvia ongelmia)

32. Mikä on korvien soimisen äänen tyyppi? (valitkaa yksi vaihtoehto)

1 = humira  
2 = sointi  
3 = pulssin syke  
4 = surinä, siltä, kohina  
5 = muu / useita ääniä

33. Koskevatko voimakkaat äänet (ääniylhärkkyys)?

0 = ei  
1 = oikea korva  
2 = vasen korva  
3 = molemmat korvat

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34. Ääni-/herkkyyden hallinta
   0 = ei hallita
   1 = heikkoa
   2 = kohtalaisa
   3 = voimakasta
   4 = erittäin voimakasta

35. Onko teillä ollut paineen tunnetta korvassa?
   0 = ei
   1 = oikea korva
   2 = vasen korva
   3 = molemmat korvat

Muut oireet

36. Onko muita oireita? (yksi tai useampi vaihtoehto)
   ei muita oireilla
   heikuttava olo
   juopuneena olon tunne
   silmässä sumpene
   epidoteellisen olon tunnetta

37. Muiden oireiden heittävuus? (valitse yksi vaihtoehto)
   0 = ei hallita
   1 = heikkoa
   2 = kohtalaisa
   3 = voimakasta
   4 = erittäin voimakasta

38. Ähdistuneisuus tai hermostuneisuus (Alheuttaako huimaus, kuulonelema tai korvien soiminen näitä oireita?)
   0 = ei
   1 = vähän
   2 = kohtalaisesti
   3 = paljon
   4 = erittäin paljon

39. Energisyys
   0 = tunnen itseni terveksi
   1 = olen hieman uupunut
   2 = olen melko voimatonta
   3 = tunnen itseni loppuun palaneeksi
   4 = tunnen itseni taysin loppuun palaneeksi

Päänsärky

Mikäli teillä esiintyy huimauskohtauksia, vastatkaa seuraaviin kysymyksiin huimauskohtausten ulkopuolella esiintyvän päänsäryn mukaan.

40. Onko teillä päänsärkyä ja mikäli on, kauanko päänsärky kestä?  
   0 = ei päänsärkyä
   1 = alle 2 tuntia
   2 = 2 tuntia - 24 tuntia
   3 = jatkuvaa päänsärkyä

Mikäli teillä ei ole päänsärkyä (kohtauskien ulkopuolella), voitte siirtyä kysymykseen 43.

41. Kuinka usein päänsärkyä esiintyy?
   1 = vähemmän kuin kerran vuodessa
   2 = vähemmän kuin kerran kuukaudessa
   3 = kuukausittain
   4 = viikoltaan
   5 = päivittäin
42. Esiinyykö teillä päällystään huimauksosaukojen aikana?

0 = ei 1 = vähän 2 = kohdallaisesti 3 = paljon 4 = aina paljon

Neurologiset oireet

43. Onko teillä pyörymiskohtauksia, joissa menetätte hetkeksi tajunnan?

0 = ei 1 = kyllä

44. Onko teillä näkökentän hämärtymistä ja sekoittumista tai kaksoiskuvia huimauksosauksten aikana?

0 = ei 1 = kyllä

45. Onko teillä äänen voimattomuutta, puheen summaallusta tai puheen takertelua huimauksosauksten aikana?

0 = ei 1 = kyllä

46. Onko teillä nielemisvaikeuksia?

0 = ei 1 = kyllä

47. Onko teillä kasvojen tumtohaisiöitä, ihotunnon alenemista tai sen puuttumista?

0 = ei 1 = kyllä

48. Onko teillä migreeniä, jonka lääkäri on todennut?

0 = ei 1 = kyllä

Alkoholi

49. Montako ravintola-annosta alkoholia (pullo keskiolutta, lasi viiniä) kuutatte viikossa?

0 = en käytä alkoholia 1 = alle 4 annosta 2 = 5 - 9 annosta 3 = 10 - 20 annosta 4 = enemmän kuin 20 annosta

Lääkkeet

50. Käytättekö nesteenpoisto- tai sydänlääkkeitä?

0 = ei 1 = kyllä

51. Oletteko saaneet tuberkuloosilääkkeitä tai muita laskimonsisääsiä lääkkeitä?

0 = ei 1 = kyllä
52. Käytättekö voimakkaampia särkylääkkeitä kuten Buranaa?

0 = ei  1 = satunnaisesti  2 = vilkoittaen  3 = päivittäin

53. Onko teiltä hoidettu pahanlaatuisten kasvaimien vuoksi?

0 = ei  1 = kyllä

54. Käytättekö mielivaltalääkkeitä?

0 = ei  1 = kyllä

55. Käytättekö psykelsääkeitä? (esim. psykoosin hoitoon käytettyjä lääkkeitä tai mielenterveystyölääkkeitä)

0 = ei  1 = kyllä

56. Käytättekö unilääkkeitä?

0 = ei  1 = kyllä

Sisäkorvan mahdolliset vammat

57. Onko teillä ollut päähän tai niskaan kohdistuvaa vammoa tai korvatulvusta, joka olisi liittynyt läheisesti huimausreiden alkuun (huimausreiden alkaneet 6 kk:n sisällä tapahtumasta)?

0 = ei  1 = kyllä

58. Oletteko käsineet aivotärähdyksestä tai iskusta päähän, josta seurannut tajuttomuus on kestynyt alle 2 tuntia?

0 = ei  1 = kyllä

minä vuonna?

59. Onko teillä ollut tajuttomuuteen johtanutta vammoa? (tajuttomuuden kesto 2 t tai enemmän)

0 = ei  1 = kyllä

minä vuonna?

60. Onko teillä ollut niskaan kohdistuvaa vammoa (esim. onnettomuudessa)?

0 = ei  1 = kyllä

minä vuonna?
61. Onko teillä ollut tuleiduksen aiheuttamaa pitkäaikaista (yli 3 kk/la) märkävuotoa korvista?
   0 = ei  1 = kyllä

62. Onko teillä ollut korvaan kohdistuvaa räjähdytystä, vammoa tai iskua, josta olisi seurannut huimausoireita?
   0 = ei .......................................................... .......................................................... .......................................................... ..........................................................
   1 = kyllä, .......................................................... .......................................................... .......................................................... ..........................................................
   minä vuonna?

63. Oletteko työssänne altistuneet voimakkaalle melulle (melutaso yli 85 dB, joka on 'kestänyt enemmän kuin 5 vuotta')?
   0 = ei  1 = kyllä

Korvaleikkauskset

64. Oletteko olette korvaleikkauskseassa?
   0 = ei  1 = en tiedä  2 = kyllä

Mikäli ette ole olette korvaleikkauskseassa, siirrykää kysymykseen 67.

65. Kumpi korva on leikattu?
   1 = oikea  2 = vasen  3 = molemmat  4 = en tiedä

Mikäli tiedätte, mitä on leikattu, vastatkaa seuraavaan kysymykseen. Jolloittie tiedätä, siirrykää suoraan kysymykseen 67 koskien muita sairauksia.

66. Onko teille suoritettu korviin kohdistuvala leikkausta huimauksen vuoksi?
   0 = ei .......................................................... .......................................................... .......................................................... ..........................................................
   1 = kyllä, .......................................................... .......................................................... .......................................................... ..........................................................
   mikä?
   minä vuonna?

Muut sairaudet

67. Sairastatteko sepelvaltimitautia?
   0 = ei  1 = kyllä

68. Sairastatteko verenpainetautia?
   0 = ei  1 = kyllä
69. Sairastattoko verisuonten kovettumatautia?
0 = ei  1 = kyllä

70. Onko teillä ollut aivoverenkierron tolmittahäiriöitä?
0 = ei  1 = kyllä

71. Sairastattoko munuaisen vajaatoimintaa?
0 = ei  1 = kyllä

72. Onko teillä sokeriautia?
0 = ei  1 = kyllä

73. Onko teillä kilpirauhasen yli- tai aihtoimintaa?
0 = ei  1 = kyllä

74. Onko teillä ollut aivokalvoutulehdusta tai sikotaudin jälkitauteja?
0 = ei  1 = kyllä

Perhehistoria

75. Onko isällänne tai äidilläne ollut huimausta tai alentunut kuulo ennen 65 v ikää?
0 = ei  1 = en tiedä  2 = kyllä

76. Onko sisarukksillanne ollut huimausta tai alentunut kuulo ennen 65 v ikää?
0 = ei  1 = en tiedä  2 = kyllä

77. Onko lapsillanne ilmennyt huonoa kuuoa?
0 = ei  1 = en tiedä  2 = kyllä

78. Jos on, niin tiedättekö huimauksen tai kuulonalennuksen syyn?
1 = en tiedä
2 = kyllä

näkä?

76
Liikunta ja fyysinen kunto

Ajattele kolmea viime kuukautta ja ota huomioon kaikki sellainen vapaa-ajan fyysinen rasisus, joka on kestänyt kerrallaan vähintään 20 minuuttia.

79. Kuinka monena päivänä herrastat verkkaista tai rauhallista liikuntaa viikossa?
   0 = en lainkaan   1 = yhtenä päivänä   2 = kahtena päivänä   3 = kolmena päivänä   4 = ainakin neljänä päivänä

80. Kuinka monena päivänä herrastat rippeää ja reipasta liikuntaa viikossa?
   0 = en lainkaan   1 = yhtenä päivänä   2 = kahtena päivänä   3 = kolmena päivänä   4 = ainakin neljänä päivänä

81. Miten arviot fyysisen kuntosi verrattuna ikätovereihisi?
   0 = selvästi huonompi   1 = jonkin verran huonompi   2 = yhtä hyvä   3 = jonkin verran parempi   4 = huomattavasti parempi
Appendix B

TERVEYTEEN LIITTYVÄN ELÄMÄNLAADEUN KYSELYLOMAKE (15D©)


KYSYMYS 1. Liikuntakyky
1 ( ) Pystyn kävelemään normaalisti (vaikeuksitta) sisällä, ulkona ja portaissa.
2 ( ) Pystyn kävelemään vaikeuksitta sisällä, mutta ulkona ja tai portaissa on pieni vaikeuksia.
3 ( ) Pystyn kävelemään ilman apua sisällä (apuvälinein tai ilman), mutta ulkona ja tai portaissa melkoisoin vaikeuksin tai toisen avustamana.
4 ( ) Pystyn kävelemään sisälläkin vain toisen avustamana.
5 ( ) Olen täysin liikuntakyvytön ja vuoteenoma.

KYSYMYS 2. Näkö
1 ( ) Näen normaalisti eli näen luukea lehteä ja TV:n tekstejä (vaikeuksitta) silmälaseilla tai ilman.
2 ( ) Näen lehtea ja tai TV:n tekstejä pienin tai varsin vaikeuksin (silmälaseilla tai ilman).
3 ( ) En näe lehtea eikä TV:n tekstejä ilman, mutta näen kulkea ilman opasta.
5 ( ) En näen kulkea oppaatta eli olen lähes tai täysin sokea.

KYSYMYS 3. Kuulo
1 ( ) Kuulen normaalisti eli kuulen hyvin normaaliala puheääntä (kuulokojeella tai ilman).
2 ( ) Kuulen normaaliala puheääntä pienin vaikeuksin.
3 ( ) Kuulen normaaliala puheääntä pienin vaikeuksin.
4 ( ) Kuulen normaaliala puheääntä heikosti; olen melkein kuuro.
5 ( ) Olen täysin kuuro.

KYSYMYS 4. Hengitys
1 ( ) Pystyn hengittämään normaalisti eli minulla ei ole hengenahdistusta eikä muita hengitysvaikeuksia.
2 ( ) Minulla on hengenahdistusta raskaassa työssä tai urheillessa, reippaassa kävelyssä tasamaalla tai levässä ylämäessä.
3 ( ) Minulla on hengenahdistusta, kun kävelen tasamaalla samaa vauhtia kuin muut ikäisieni.
4 ( ) Minulla on hengenahdistusta pienienkin rasituksen jälkeen, esim. peseytyessä tai pukeutuessa.
5 ( ) Minulla on hengenahdistusta lähes koko ajan, myös levossa.

15D©/Harri Sintonen (www.15D-instrument.net)
KYSYMYS 5. Nukkuminen
1 ( ) Nukun normaalisti eli minulla ei ole mitään ongelmia unen suhteen.
2 ( ) Minulla on lieviä uniongelmia, esim. nukahtamisvaikeuksia tai satunnaista yöheräilyä.
3 ( ) Minulla on melkoisia uniongelmia, esim. nukun levottomasti tai uni ei tunnu riittävästi.
4 ( ) Minulla on suuria uniongelmia, esim. joudun käyttämään usein tai säännöllisesti unilääkettä, herään säännöllisesti yöllä ja/tai aamuisin liian varhain.
5 ( ) Kärsin vaikeasta unettomuudesta, esim. unilääkkeiden runsaasta käytöstä huolimatta nukkuminen on lähes mahdotonta, valvon suurimman osan yöstä.

KYSYMYS 6. Syöminen
1 ( ) Pystyn syömään normaalisti eli itse ilman mitään vaikeuksia.
2 ( ) Pystyn syömään itse pienin vaikeuksin (esim. hitaasti, kömpelösti, vavisten tai erityisapuneuvoin).
3 ( ) Tarvitsen hieman toisen apua syömisessä.
4 ( ) En pysty syömään itse lainkaan, vaan minua pitää syöttää.
5 ( ) En pysty syömään itse lainkaan, vaan minulle pitää antaa ravintoa letkun avulla tai suonensisäisesti.

KYSYMYS 7. Puhuminen
1 ( ) Pystyn puhumaan normaalisti eli selvästi, kuuluvasti ja sujuvasti.
2 ( ) Puhuminen tuottaa minulle pieniä vaikeuksia, esim. sanoja on etsittävä tai ääni ei ole riittävän kuuluvaa tai se vaihtaa korkeutta.
3 ( ) Pystyn puhumaan ymmärrettävästi, mutta katkonaisesti, ääni vavisten, sammaltaen tai äänkättäen.
4 ( ) Muilla on vaikeuksia ymmärtää puhettani.
5 ( ) Pystyn ilmaisemaan itseäni vain elein.

KYSYMYS 8. Eritystoiminta
1 ( ) Virtsarakkoni ja suolistoni toimivat normaalisti ja ongelmitta.
2 ( ) Virtsarakkoni ja/tai suolistoni toiminnassa on lieviä ongelmia, esim. minulla on virtsaamisvaikeuksia tai kova tai löysä vatsa
3 ( ) Virtsarakkoni ja/tai suolistoni toiminnassa on melkoisia ongelmia, esim. minulla on satunnaisia virtsanpidätysvaikeuksia tai vaikea ummetus tai ripuli.
4 ( ) Virtsarakkoni ja/tai suolistoni toiminnassa on suuria ongelmia, esim. minulla on säännöllisesti ”vahinkoja” tai peräruiskeiden tai katetroinnin tarvetta.
5 ( ) En hallitse lainkaan virtsaamista ja/tai ulostamista.
KYSYMYS 9. Tavanomaiset toiminnot

1 ( ) Pystyn suoritumaan normaalisti tavanomaisista toiminnoista (esim. ansiotyö, opiskelu, kotityö, vapaa-ajan toiminnot).
2 ( ) Pystyn suoritumaan tavanomaisista toiminnoista hieman alentuneella teholla tai pienin vaikeuksin.
3 ( ) Pystyn suoritumaan tavanomaisista toiminnoista huomattavasti alentuneella teholla tai huomattavrin vaikeuksin tai vain osaksi.
4 ( ) Pystyn suoritumaan tavanomaisista toiminnoista vain pieneltä osin.
5 ( ) En pysty suoritumaan lainkaan tavanomaisista toiminnoista.

KYSYMYS 10. Henkinen toiminta

1 ( ) Pystyn ajattelemaan selkeästi ja johdonmukaisesti ja muistini toimii täysin moitteettomasti.
2 ( ) Minulla on lieviä vaikeuksia ajatella selkeästi ja johdonmukaisesti, tai muistini ei toimi täysin moitteettomasti
3 ( ) Minulla on melkoisia vaikeuksia ajatella selkeästi ja johdonmukaisesti, tai minulla on jonkin verran muistinmenetystä
4 ( ) Minulla on suuria vaikeuksia ajatella selkeästi ja johdonmukaisesti, tai minulla on huomattavaa muistinmenetystä
5 ( ) Olen koko ajan sekaisin ja vailla ajan tai paikan tajua

KYSYMYS 11. Vaivat ja oireet

1 ( ) Minulla ei ole mitään vaivoja tai oireita, esim. kipua, särkyä, pahoinvointia, kutinaa jne.
2 ( ) Minulla on lieviä vaivoja tai oireita, esim. lievää kipua, särkyä, pahoinvointia, kutinaa jne.
3 ( ) Minulla on melkoisia vaivoja tai oireita, esim. melkoista kipua, särkyä, pahoinvointia, kutinaa jne.
4 ( ) Minulla on voimakkaita vaivoja tai oireita, esim. voimakasta kipua, särkyä, pahoinvointia, kutinaa jne.
5 ( ) Minulla on sietämättömiä vaivoja ja oireita, esim. sietämätöntä kipua, särkyä, pahoinvointia, kutinaa jne.

KYSYMYS 12. Masentuneisuus

1 ( ) En tunne itseäni lainkaan surulliseksi, alakuloiseksi tai masentuneeksi.
2 ( ) Tunnen itseni hieman surulliseksi, alakuloiseksi tai masentuneeksi.
3 ( ) Tunnen itseni melko surulliseksi, alakuloiseksi tai masentuneeksi.
4 ( ) Tunnen itseni erittäin surulliseksi, alakuloiseksi tai masentuneeksi.
5 ( ) Tunnen itseni äärimmäisen surulliseksi, alakuloiseksi tai masentuneeksi.
KYSYMYS 13. Ahdistuneisuus
1 ( ) En tunne itseäni lainkaan ahdistuneeksi, jännittyneeksi tai hermostuneeksi.
2 ( ) Tunnen itseni hieman ahdistuneeksi, jännittyneeksi tai hermostuneeksi.
3 ( ) Tunnen itseni melko ahdistuneeksi, jännittyneeksi tai hermostuneeksi.
4 ( ) Tunnen itseni erittäin ahdistuneeksi, jännittyneeksi tai hermostuneeksi.
5 ( ) Tunnen itseni äärimmäisen ahdistuneeksi, jännittyneeksi tai hermostuneeksi.

KYSYMYS 14. Energisyys
1 ( ) Tunnen itseni terveeksi ja elinvoimaiseksi.
2 ( ) Tunnen itseni hieman uupuneeksi, väsyneeksi tai voimattomaksi.
3 ( ) Tunnen itseni melko uupuneeksi, väsyneeksi tai voimattomaksi.
4 ( ) Tunnen itseni erittäin uupuneeksi, väsyneeksi tai voimattomaksi, lähes "loppuun palaneeksi".
5 ( ) Tunnen itseni äärimmäisen uupuneeksi, väsyneeksi tai voimattomaksi, täysin "loppuun palaneeksi".

KYSYMYS 15. Sukupuolielämä
1 ( ) Terveydentilani ei vaikeuta mitenkään sukupuolielämääni.
2 ( ) Terveydentilani vaikeuttaa hieman sukupuolielämääni.
3 ( ) Terveydentilani vaikeuttaa huomattavasti sukupuolielämääni.
4 ( ) Terveydentilani tekee sukupuolielämääni lähes mahdottomaksi.
5 ( ) Terveydentilani tekee sukupuolielämääni mahdottomaksi.
Appendix C

Terveyteen liittyvän elämänlaadun kyselylomake (EQ-5D)


Liikkuminen
☐ Minulla ei ole vaikeuksia kävelemisessä
☐ Minulla on jonkin verran vaikeuksia kävelemisessä
☐ Olen vuoteenomana

Itsestään huolehtiminen
☐ Minulla ei ole vaikeuksia huolehtia itsestäni
☐ Minulla on jonkin verran vaikeuksia peseytyä tai pukeutua itse
☐ En kykene peseytymään tai pukeutumaan itse

Tavanomaiset toiminnnot (esim. ansiotyö, opiskelu, kotityö, vapaa-ajan toiminnot)
☐ Minulla ei ole vaikeuksia suorittaa tavanomaisia toimintojani
☐ Minulla on jonkin verran vaikeuksia suorittaa tavanomaisia toimintojani
☐ En kykene suorittamaan tavanomaisia toimintojani

Kivut / vaivat
☐ Minulla ei ole kipuja tai vaivoja
☐ Minulla on kohtalaisia kipuja tai vaivoja
☐ Minulla on ankaria kipuja tai vaivoja

Ahdistuneisuus / masennus
☐ En ole ahdistunut tai masentunut
☐ Olen melko ahdistunut tai masentunut
☐ Olen erittäin ahdistunut tai masentunut
Auttaaksemme ihmisiä sanomaan, kuinka hyvä tai huono jokin terveydentila on, olemme piirtäneet lämpömittaria muistuttavan asteikon. Paras terveydentila, jonka voitte kuvitella, merkitään siinä 100:lla ja huonointa 0:lla.

Haluaisimme Teidän osoittavan tällä asteikolla, miten hyvä tai huono Teidän terveyteen on mielestänne tänään. Olkaa hyvä ja tehkää tämä vetämällä alla olevasta laatikosta viiva siihen kohtaan asteikolle, joka osoittaa, miten hyvä tai huono terveydentilaanne on tänään.
Appendix D

Kaatumiskysely

Oletteko kaatuneet viimeisen kolmen kuukauden aikana?
Kyllä
Ei

Missä kaatuminen tapahtui?
Sisällä
Ulkona
Kuvaile olosuhteita: ____________________________

Miten kaatuminen tapahtui?
Liukastuminen
Kompastuminen
Nousun yhteydessä
Sängystä tippuminen
En tiedä syytä
Muu: ____________________________

Oliko kaatumiselle jokin tietty syy, esim liukas lattia, jäätynyt tie tai huimaus?

Oliko kaatumisella silmännäkijöitä?
Kyllä
Ei

Seurasiko kaatumisesta tajutomuus?
Kyllä
Ei

Kävittekö kaatumisen jälkeen lääkäriin?
Kyllä
Ei

Oliko kaatumisella terveydellisiä seurauksia?
Kyllä
Ei

Jos vastasitte Kyllä, mitä seurauksia kaatumisesta oli?

__________________________

84
### Kaatumisen pelko

Tämän kyselyn tarkoituksena on selvittää, kuinka huolestuneita olette mahdollisesta kaatumuksesta. **Valitkaa seuraavista vaihtoehtoista tuntemanne taso, kun suoritat kyseisiä askareita.** Vastatkaa sen mukaan, miten käytännössä yleensä suoritat askareen. **Jos ette enää itse suorita jotain kyseisistä askareista, vastatkaa sen mukaan, mitä se tuntuisi jos vielä suorittaisit kyseistä askaretta.**

<table>
<thead>
<tr>
<th>numero</th>
<th>Kysymys</th>
<th>En pelkää suorittaa itsenäisesti</th>
<th>Pelkäään hieman suorittaa itsenäisesti</th>
<th>Pelkäään suorittaa itsenäisesti</th>
<th>Pelkäään todella paljon suorittaa itsenäisesti</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Siivoaminen (lakaisu, imurointi, pölyjen pyyhkiminen)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.</td>
<td>Pukeutuminen ja riisuuntuminen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3.</td>
<td>Yksinkertaisten aterioiden valmistaminen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4.</td>
<td>Saunassa tai suihkussa käynti</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5.</td>
<td>Kaupassa käynti</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6.</td>
<td>Tuolille istuuntuminen ja tuoliitta nousu</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7.</td>
<td>Portaissa kulkeminen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8.</td>
<td>Kävely asunnon lähistöllä</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9.</td>
<td>Pään yläpuolella olevan esineen kurkottaminen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10.</td>
<td>Käirehtiminen vastata puhelimseen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>11.</td>
<td>Kävely liukkaalla pinnalla (märkää tai jäänen)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>12.</td>
<td>Vierailu ystävän tai sukulaisen luona</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13.</td>
<td>Väkijoukossa liikkuminen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>14.</td>
<td>Epäetasaisella pinnalla kävely (esim. huonosti hoidettu jalkakäytävä tai kivinen maasto)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15.</td>
<td>Jyrkähköä rinnettä ylös tai alas kävely</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>16.</td>
<td>Erlaisiin tapahtumiin osallistuminen (esim. jumalanpalvelus tai sukujuhlat)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
## Appendix F

**MINI-MENTAL STATE EXAMINATION**

**POTILAS:**

**SYNTYNÄAKA:**

**TUTKJA:**

**PVM:**

Seuraavassa esitetään Teille erilaisia pieniä muistin ja älyllisiin toimintoihin liittyviä kysymyksiä ja tehtäviä:

<table>
<thead>
<tr>
<th></th>
<th>Värin</th>
<th>Oikein</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mikä vuosi nyt on?</td>
<td>0</td>
</tr>
<tr>
<td>2.</td>
<td>Mikä vuodenalka nyt on?</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(taiv = joulu, tammi, heinä)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>kevat = maalis, huhti, touko</td>
<td></td>
</tr>
<tr>
<td></td>
<td>kesä = kesä, heinä, eli</td>
<td></td>
</tr>
<tr>
<td></td>
<td>syksy = syys, lokka, marras; aika = 1 viiko)</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Moneksi päivä tänään on? (± 1 pv)</td>
<td>0</td>
</tr>
<tr>
<td>4.</td>
<td>Mikä viikonpäivä tänään on?</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td>Mikä kuukausi nyt on?</td>
<td>0</td>
</tr>
<tr>
<td>6.</td>
<td>Missä maassa olemme?</td>
<td>0</td>
</tr>
<tr>
<td>7.</td>
<td>Missä maakunnassa olemme?</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(Myös vanhan laajennan mukaiset vastaukset hyväksytään)</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Mikä on tämän paikkakunnan nimi?</td>
<td>0</td>
</tr>
<tr>
<td>9.</td>
<td>Mikä on tämä paikka jossa olemme?</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(Sairaanlääken/terveyskeskuksen nimi; kotiosoitte)</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Monenessako kerroksessa olemme?</td>
<td>0</td>
</tr>
<tr>
<td>11.</td>
<td>Seuraavassa pyydän Teitä painamaan mieleen kolme sanaa. Kun olen sanonut ne, toistaa perässäni. (Kaksia vaihtoehtoista sarjaa)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PAITA – RUSKEA – VILKAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RUSUUS – PALLO – AVAIN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Merkitä ensimmäisellä kerralla muistutat sanat)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jos ensimmäisessä toistossa tulee viheitä, sanootte vastaavaan sanaan on oottu.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tostoa (enintään 5 kertaa)</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Nyt pyydän Teitä vähentämään 100:sta 7 ja saamasta jaanoksesta 7 ja edelleen vähentämään 7, kunnes pyydän lopettamaan.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>83.....</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>86.....</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>79.....</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>72.....</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>65.....</td>
<td>0</td>
</tr>
</tbody>
</table>

(Kysymys voidaan toistaa kerran, jos sitä ei halutu käyttää. Jos henkilö lekelee vallia virheen, mutta jatkaa sitä oikein vähentäen 7 viiteellisestä luvusta, tulee välia vastauksia 1. Kylälä ja paperia ei saa käyttää.)

**MMSE-testin pistemäärä:** 30

KÄÄNNÄ
Kirjoitaisitteko lauseen tähän.

Pirtaisitteko tämän kuvion alapuolelle samantaisen kuvion.


Video-oculography, Micromedical Technologies, Inc. Chatham, Illinois, USA.


Characterization of presbyequilibrium among institutionalized elderly persons

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ABSTRACT

Objective: The aim was to characterize dizziness, vertigo, poor maintenance of posture, and sudden instabilities (called presbyequilibrium) among institutionalized elderly to model and identify possible treatable causes.

Methods: A questionnaire based study focusing on symptoms among 72 elderly persons from a single residential facility and followed them for 3 years.

Results: Dizziness, vertigo, poor maintenance of posture, and black-outs were reported by 68% of the 72 elderly and make them at risk for falls, and reduced quality of life. The most common complaint was postural instability, with a tendency to fall. “Spinning” vertigo and “floating” sensation had a strong inter-correlation and correlated with habitual falls. The various dizziness symptoms often occurred in combinations. Attacks of self-experienced syncope never occurred alone but always in combination with “spinning vertigo” or “tendency to fall”. In factorial analysis, presbyequilibrium could be divided into six categories. Two of these categories correlated with falls.

Conclusions: Among elderly, presbyequilibrium is commonly characterized by a combination of phenomena involving perceptual, orientation, postural, and autonomic manifestations. It is often difficult to obtain an accurate history from the elderly and the presence of vestibular symptoms is frequently overlooked. Taking a careful history and utilizing the classification of symptoms that emerged from the factorial analysis may give a deeper understanding of the etiology of presbyequilibrium, thereby facilitating appropriate rehabilitation.

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1. Introduction

Vertigo and dizziness in the elderly are common complaints that have been reported among 30% of elderly over 65 years of age [1] and increasing to 60% among the elderly over 85 years of age [2]. In addition, dizziness and vertigo in the elderly lead to fear of falling, and reduction of mental and physical health [3]. Balance problems, dizziness and impaired sensory function are associated with depression, increased medication use, increased weight, decreased muscle strength and vascular disease [2,4,5].

In various population-based studies, subjective reporting of dizziness, has been regarded as a significant predictor for falls [6–10]. In addition to the common problems that contribute to dizziness in the elderly, subtle vestibular pathology such as otolithic disorders may also create dizziness complaints [11,12]. Consequently, the vestibular complaints may signal from epiph- nomenon of malfunction of the vestibular system and require specific approaches to design intervention and falls prevention, different from those linked to medication and general activity restrictions.

To date, it has been a challenge to characterize vertigo, dizziness and poor postural stability in the elderly. These symptoms are usually considered by practitioners to be part of a “geriatric syndrome” because of their multi-symptomatic appearance. In a chart audit, Kwong and Pimlott [13] showed that 46% of elderly who came for primary consultation for vertigo, were either diagnosed improperly or were considered to be simply symptomatic of their natural aging process. From Gothenburg’s longitudinal study it is evident that the elderly describe their symptoms in various, non-uniform ways [2]. Some patients report true vertigo, a hallucination of motion that is most commonly a distinct sensation of rotation or rocking. Others describe their dizziness as a sensation of unsteadiness, imbalance, disequilibrium and a feeling of unreality. Also reported are orthostatic obscuration of vision and even loss of consciousness.

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The evaluation of dizziness in geriatric patients is often a frustrating experience for physicians due to the difficulties in sorting through the multiple symptoms that geriatric patients often possess, the lack of specific physical examination findings or diagnostic tests for balance disorders, and the wide range of potential causes of balance disorders. Belal and Glogir [22] introduced the word “presbyaesthesia” to describe the vertigo of ageing. We have used the term presbyequilibrium in analogy to presbycusis. In trying to understand what patients mean with the one word, “dizziness or vertigo,” doctors usually use several words to attempt to better define the nature of the disorder with terms such as “balance problems,” “gait problems,” “giddiness,” “fear of falling,” “light-headedness,” “heavy feeling,” “emptiness of the head,” “black-outs,” “slips,” “sudden instabilities” or “falls,” “spinning of the environment” or “spinning sensation within the head.” In the present study we included most of these terms or concepts into the questionnaire and analyzed their content as symptom entities of presbyequilibrium.

By improved understanding of age related instability and dizziness, it is possible to streamline the diagnostic and therapeutic processes that, in turn, could aid patients to develop better means for maintaining “balance fitness.” These endeavors would ultimately help to prevent accidental falls. Because of the wide variation of presbyequilibrium signs and symptomatology, a deeper understanding of a patient’s symptoms may help greatly to define the aetiological factors and aid in directing appropriate treatment. To our knowledge, there are no systematic studies conducted on matters relating to presbyequilibrium in institutionalized elderly people. The purpose of the present study was to establish the characteristics of presbyequilibrium among very old persons living in an elderly home and to study the associations between etiology and falls, quality of life and memory impairment in order to understand any internal associations. Finally, we also studied whether any of the factor or complaint could explain the accidental fall and a risk for death by following 3 years of these elderly subjects.

2. Methods

2.1. Patients

We performed our study of institutionalized very old persons living in the Koukkuniemi elderly home in Tampere, Finland. The City of Tampere institutional review board approved the study protocol. Of the 896 residents in the home, 156 were selected by the nurses on the basis of subjects’ willingness to participate in the study and their demonstrated ability to rise to standing from a chair without requiring use of their hands. Twenty residents opted out of the study before completion, and 64 were transferred to another home or died before the completion of the study. Therefore, 72 subjects were included in the study. The subjects were followed for three years and their survival rates were evaluated.

The complete set of data collected consisted:

1. History and character of dizziness and postural stability with otoneurological questionnaire [14].
2. General quality of life analyzed with 15D questionnaire (QoL-15D) [15].
3. The mini mental status examination (MMSE) short scale [16].
4. Number of falls and possible aetiology.
5. Orthostatic blood pressure.

Orthostatic blood pressure is measured first after lying down for 15 min, second right after standing up and third after three minutes standing up [17].

2.2. Demographics

72 elderly subjects were entered into the study; 58 were females and 14 males (mean age 87.0 years range 70–101 years). 25 subjects had MMSE scores of 24 or less and 48 had MMSE scores 25 or better. After three years, 42 subjects were living and 30 had died.

2.3. Otoneurological questionnaire

The otoneurological questionnaire consists 98 questions about medical history, medication, symptoms of vertigo or dizziness and balance problems [14,18,19]. When necessary subjects’ interviews were confirmed or augmented from interviews with their personal nurses who served as proxies. Additionally, subjects’ medical records were reviewed to obtain a complete medical history and to record all data regarding falls.

In the otoneurological questionnaire the presence of the following items were used in the primary analysis:

1. feeling of rotation,
2. feeling of floating,
3. tendency to fall,
4. postural instability when moving,
5. sudden drops of balance without losing consciousness.

Occurrence of these symptoms as isolated or in combination was studied and their severity was evaluated in a more detailed questions that further characterized the symptoms.

2.4. Character of dizziness and vertigo

The case history was explored to categorize the often vague and imprecise symptoms expressed by the subjects into consistent and more precisely defined terms. Dizziness and vertigo were broken down into more detail as rotatory vertigo, dizziness, movement instability, fear of falling, sudden loss of balance, light headiness, floating sensation and/or black-out. In addition, some related symptoms such as feeling of unreality, loss of vitality, nervousness and reduced mobility were queried. Occurrence of vertigo, duration of spells, and provoking factors were asked. Subjects’ limitation of activities due to symptoms was rated. Symptoms of hearing loss, tinnitus, and associated symptoms such as nausea or vomiting were queried. Finally, the effect of vertigo or dizziness on subjects’ everyday life was evaluated.

2.5. Associating factors

Patient charts for neurological symptoms and disorders were reviewed and the history included possible attacks of syncope or near syncope, and malfunction of specified cranial nerves.

Ability to move and arise from a chair was addressed with four questions. These focused on the elderly person’s ability to walk when not acutely affected by vertigo spells and inquired about the general severity of any balance problems.

Possible injuries in the inner ear and ear surgeries were addressed with questions that focused on the temporal relationship between any injuries, ear infections, chronic noise exposure, acoustic trauma or ear surgery.

Medical history and medications were obtained from the subjects’ medical records and from interviewing the ward staff.

2.6. Statistics

The results were analyzed using the approach to qualitative analysis described by Craneheim and Lundman [20]. This analysis classifies and compares groups of responses. The associations were
evaluated with correlation analysis, that in continuous variables used Pearson’s and in class variables Kendall’s correlation.
Thereafter, the variables were analyzed in factorial analysis using varimax rotations. The new unit of analysis (meaning unit) comprises the symptoms the respondents. The qualitative analyses in this study were conducted independently by two of the researchers. A process of reflection and discussion including four authors resulted in agreement on the final set of themes identified.

3. Results

3.1. History of presbyequilibrium

The first question focused on whether the elderly subjects had any symptom of dizziness, vertigo or balance problems and the outcome was reported as presbyequilibrium. From the 72 elderly subjects, 49 (68%) indicated a presence of presbyequilibrium whereas 23 (32%) did not report any presbyequilibrium in response to this question. Females reported presbyequilibrium more frequently than males ($\chi^2 = 27.9$, $p < 0.001$).

Fig. 1 shows the underlying symptoms for presbyequilibrium. The tendency to fall was the most prominent single symptom as well as the symptom most commonly found in combination with other symptoms. Syncope and near syncope never occurred alone but always in connection with other symptoms.

The majority of the group suffered from vertigo and dizziness everyday (22 cases) followed by once a week (15 cases). Six had episodic symptoms once a month and four had symptoms less than once a month. Two announced having symptoms less than once a year. These attacks were typically an hour long and were linked to moderately strong nausea. During the attacks, subjects had to either lay down or at least stop all other activities.

The duration of vertigo and dizziness was grouped into five categories ranging from less than minute to constant and is shown in a histogram in Fig. 2.

The intensity of vertigo and dizziness was classified into five categories based on the degree of temporary interference in their daily activities at that time (Fig. 3). The most common intensity score (19 cases) was “moderately strong,” meaning that the subjects had to abandon their daily activities in order to manage the vertigo or dizziness. The second most common (15 cases) intensity score was “mild” meaning that the subject was affected by the dizziness but did not have to abandon their activities. Twelve subjects had “strong” vertigo or dizziness and had to rest during the spell. Two reported their dizziness was “extremely strong”. One had very mild dizziness that did not influence on daily activities.

Sudden instability episodes were reported by 28 subjects. These attacks were characterized as very brief (few seconds or less) losses of balance or consciousness during which the person actually fell or had to seek support to prevent a fall. One example of such an episode would be a classic Tumarkin otolithic attack. Sudden instabilities were associated (with Kendall’s tau) with symptoms of postural instability ($r = 0.39$, $p = 0.001$), tendency to fall ($r = 0.29$, $p = 0.012$) and reduction of quality of life ($r = -0.21$, $p = 0.026$) indicating fault in the activation of the vestibulospinal reflexes.

![Fig. 1. Association of different symptoms of vertigo in elderly. 1 = rotatory vertigo; 2 = floating sensation = postural instability; 3 = rotatory vertigo associated with postural instability; 4 = tendency to fall; 5 = tendency to fall, associated with postural instability = poor postural stability; 6 = rotatory vertigo, associated with tendency to fall and postural instability = gait problems; 7 = syncope and near syncope associated with rotatory vertigo, tendency to fall and postural instability; 8 = syncope associated with tendency to fall.](image1)

![Fig. 2. N = 49. Duration of presbyequilibrium: 1 = less than 1 min, 2 = >1–20 min, 3 = >20 min to 4 h, 4 = >4–24 h, 5 = constant vertigo.](image2)

![Fig. 3. N = 49. Intensity of presbyequilibrium: 1 = very mild, no influence on daily activities; 2 = mild, influence on activities but can continue with them; 3 = moderate, interferes with daily activities and has to interrupt the ongoing activity; 4 = strong, has to rest; 5 = severe, disabling symptoms continue even at rest.](image3)
3.2. Modeling of vertigo of elderly

We performed factor analysis (varimax rotation) to identify internal associations of presbyequilibrium. In this analysis, 6 major components were identified that described 75 per cent of the data regarding symptoms of presbyequilibrium in the elderly subjects. The six components could be further classified by their characteristics and named to describe their component of presbyequilibrium. The associations are highlighted in Table 1. The postural instability was a symptom in four of the six factors.

Vestibular irritability (Factor 1) contained characteristics that indicated a “vestibular mismatch”. The subjects had symptomatic paroxysmal vertigo that was provoked by physical strain or activity and was often accompanied by nausea during the attack. These subjects tended to experience sudden instability episodes and there was an association with sudden postural instability. It correlated with reduced general measure of quality of life \((r = 0.30, p = 0.037)\).

Positional vertigo (Factor 2) was characterized by postural instability, had frequent episodes and was provoked by position and physical strain. Subjects had frequent attacks of postural instability. It correlated with reduced physical performance \((r = 0.32, p = 0.006)\).

The vestibular failure (Factor 3) was characterized by rotatory type of vertigo or by floating sensations. It correlated significantly with impending death \((r = 0.31, p < 0.031)\) and reduction of vitality \((r = 0.32, p = 0.021)\).

Frail presbyequilibrium (Factor 4) was characterized by poor muscle strength and coordination and the need for assistance in movements. These subjects preferred to use their hands to assist themselves when rising from a chair and used supporting devices for walking. It correlated significantly with loss of vigilance \((r = 0.33, p = 0.021)\), poor motility \((r = 0.61, p > 0.001)\), poor vision \((r = 0.33, p = 0.003)\) and reduction of MMSE score \((r = 0.28, p = 0.014)\). We also noticed that it correlated with habitual falls \((r = 0.31, p = 0.010)\).

Autonomic vertigo (Factor 5) was characterized by episodes of syncope or near syncope, or intense vertigo requiring bed rest with delayed recovery. It correlated with anxiety \((r = 0.51, p = 0.001)\), reduction of vitality \((r = 0.31, p = 0.031)\) and falls \((r = 0.25, p = 0.041)\).

Finally, movement intolerance (Factor 6) was characterized by a constant feeling of dizziness, often with nausea. It was associated with instability but without tendency to fall. It correlated with reduction of MMSE score \((r = 0.22, p = 0.033)\) and subjective impairment in memory \((r = 0.285, p = 0.012)\).

4. Discussion

The words “vertigo” and “dizziness” have different definitions for doctors and patients and vary in different societies. The word dizziness in Webster’s New World Dictionary is defined as, “feeling giddy or unsteady, causing giddiness, confused, or silly.” The definition given for giddiness is “having or causing a whirling, unsteady sensation; dizzy; frivolous.” The word vertigo is defined as, “sensation of dizziness.” The interchangeable use of these terms to define themselves is evidence of the difficulty in characterizing these sensations into language. In contrast, medical dictionaries attempt to narrow the definitions of some words such that in some societies, the term “vertigo” implies a whirling sensation and “dizziness” is used to mean a nonspecific disorder linked with disorientation in space. However, the elderly understand and describe their dizziness in many ways and often they tend to underreport their symptoms. They commonly use various nonspecific terms to describe their complaints of balance disorders, such as vertigo, general unsteadiness, dizziness, lightheadedness, fainting or other illusory sensations as indications of medically specific symptoms of true vertigo. In addition, fear of falling, gait disorders, postural mis-match, oscillopsia, syncope or near syncope, may also be expressions of dizziness. We used the term presbyequilibrium, in analogy to presbycusis, to encompass the wide range of perceived losses of control in space that patients characteristically experience with ageing.

Jönsson et al. [2] observed that the prevalence of vertigo and dizziness increases with age (correlation coefficient 0.9) ranging from about 30% at the age of 70 years to about 50% at the age of 85 or more supporting the findings in the present study. Our report confirms the observations that at least 50% of all older people with dizziness complain of two different types of dizzy symptoms [21]. We are not aware of any other studies in that presbyequilibrium has been explored in institutionalized very old subjects. Usually these subjects have other health problems, as also in the present study, and their balancing problems, dizziness and vertigo are regarded as a nuisance and an ultimate course caused by ageing. Consequently, the primary care clinicians and geriatricians commonly under-diagnose or misdiagnose dizziness and vertigo.
in the elderly. This attitude should be changed as the number of aged population will increase and understanding the cause of the problems can lead to better prevention and therapy.

Several authors have recognized that presbyequilibrium is associated with impaire health-related quality of life [8–10]. Jönsson et al. [2] reported that presbyequilibrium was regarded as an obstacle to daily activities by up to 26% of the elderly. The severity of the QoL-15 impairment was proportional to poor vestibular coping also in this study. These data suggest that balance problems are a major limiter of daily activities in persons 75 years or older. Belal and Glogging [22] studied dizzy patients over the age of 65 and found specific causes of dizziness in 21% of the material. In the remaining 79% no specific diagnostics could be established, and the authors coined the term “primary disequilibrium of ageing” for these cases. Tuunainen et al. [23] studied vide-ooctography among oldest olds and showed specific diagnosis among 40% of the cases but the nystagmus findings had loose connection with presbyequilibrium, as elderly could not recall vertigo even if oculographic findings indicated benign positional nystagmus. The elderly may regard also by themselves the symptoms as age related. Therefore presbyvertigo may be more prevalent than reported.

Based on factorial analysis we observed six different entities in presbyequilibrium, which could be linked to therapeutically meaningful groups. The vestibular irritability (Factor 1) contained components of nausea, sudden instabilities and the problems were provoked by physical strain and environmental pressure change. In addition it was linked to postural instability. These changes may be related to vascular and degenerative changes of VOR shown by Kerber et al. [24].

Positional vertigo (Factor 2) may represent otolith disorders, Menière’s disease, and other peripheral vestibular injuries. Lawson et al. [25] and Tuunainen et al. [23] demonstrated that elderly with benign paroxysminal positional vertigo (BPPV) often did not report the classically described symptoms. Elderly patients who were referred directly to their fall unit and who were found to have BPPV were compared with younger “classical” patients with BPPV. The elderly were significantly more likely to describe dizziness with postural change (40% vs. 14%) and less likely to describe rotatory vertigo (40% vs. 89%). In addition, 45 per cent of the elderly patients had more than one type of dizziness. It was noteworthy that in the elderly group there had been no previous provisional diagnosis of BPPV or positional vertigo made by their primary care practitioner. The authors concluded that making a diagnosis of BPPV in older people may be difficult, particularly as this group frequently has more than one type of dizziness, may describe postural dizzy symptoms (raising the suspicion of orthostatic hypotension), and may have multiple co-morbidity and coexistent cardiovascular diagnoses.

Postural changes in our previous study did not commonly provoke nausea [23]. Neither Oghalai et al. [11] nor Katsarkas [12] reported nausea in their studies of elderly. Probably the elderly try to minimize their head movements to avoid nausea and dizziness. The elderly with symptoms classified to Factor 4 also experienced sudden instabilities and attacks of black outs, yet they did not report losing consciousness, possibly because they experienced amnesia [26,27]. Taken to the extreme, the characteristics of Factor 4 can mimic the Tumarkin attacks of Meniere’s disease that originate from a crisis in the otoletic system [28].

Vestibular failure (Factor 3) showed some correlations that could be of either central or peripheral vestibular failure. Factor 3 correlated significantly with impending death and also included associations with syncope near syncope and unexplained sudden instabilities. We therefore consider that this component may be, at least in part, of central origin. Supporting our hypothesis is the finding of Fife and Baloh et al. [29] who demonstrated that rotatory vertigo in elderly was linked to vascular degeneration of the white matter. However, Hirvonen et al. [30] observed in head autorotation tests that in the oldest olds, the gain was elevated at high frequencies with simultaneous prolongation of the time constant. The authors interpreted that the changes were compensatory due to stiffness of the effector system combined with low onset of torque and prolonged sensory processing time. We therefore suggest that this Factor 3 component could also represent peripheral VOR failure.

The vestibular frail–syndrome (Factor 4) correlated significantly with loss of vigilance, motility, vision and subjective impairment in memory. These risk factors were much the same as observed by Stevens et al. [10] and Pluijm et al. [8]. Functional limitation was among the most important risk factors that encompassed dizziness and hand grip force in these studies.

In the present study, autonomic vertigo (Factor 5) was classified by the characteristics of syncope and intensity of the episodes being sufficiently strong as to force the patient to rest during attacks. Staab and Rükenstein [31] introduced the term “auto-nomic dizziness” in the vestibular literature. Patients with autonomic dizziness frequently report that symptoms are trig-gered by physical straining without provocative head movements [31]. Exercise-induced syncope has received considerable atten-tion because of its dramatic presentation as a sudden loss of consciousness in otherwise healthy young athletes [32]. The autonomic vertigo factor was associated with accidental falls. This factor has many similarities with the cardio-inhibitory and hypotensive vasovagal or neurocardiogenic syndrome (NCS) attacks affecting the elderly. NCS is characterized by hypotension with or without bradycardia and in the elderly, it is a common, benign condition that is not associated with increased mortality [33,34]. In NCS about 20 per cent of the patients report only experiencing dizziness whereas about 69 per cent had both syncope and dizziness [27]. The symptoms can be significantly recurrent [27].

In the present study we named Factor 6 “movement intolerance” as it was characterized by constant dizziness and not provoked by specific head movements. There was association with postural instability and nausea. Noteworthy was that this factor correlated significantly with coronary heart disease. The character-istics of Factor 6 are similar to Mal-de-debarquement syndrome in that the elderly do not properly adapt to a change in vestibular function. It may involve impairment in the postural memory or pathways controlling vestibular memory as we observed an association between MMSE scores and the movement intolerance factor.

5. Conclusions

It is apparent that elderly patients often fail to report dizziness symptoms unless specific inquiries are made and that they often do not consciously recognize dizziness or balance problems as an abnormality that should be investigated. For these reasons, it is important for practitioners to maintain a high awareness about balance disorders in the elderly and to specifically inquire about these symptoms during the history and to exam for signs of these often treatable conditions. We would suggest that services for dizzy patients should allow for efficient, seamless movement between “falls” clinics run by geriatricians and a balance/vertigo service run by otolaryngology physicians and surgeons. They should collaborate and have joint working schedules to optimize the management and the sometimes difficult assessment of presbyequilibrium.

Conflict of interest

None of the authors or their institutions have a conflict of interest in financial or personal relationships with other people or
organizations that could inappropriately influence (bias) their actions in writing this work.

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References

Presbyequilibrium in the oldest old, a combination of vestibular, oculomotor and postural deficits

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ABSTRACT. Background and aims: Dizziness, impaired balance and fear of falling are common complaints in the elderly. We evaluated the association of vestibular symptoms with vestibular findings in the elderly by posturography and video-oculography (VOG).

Methods: We studied 38 oldest old subjects (≥85 yrs, mean age 89) living in a residential home. Vestibular symptoms were taken with a structured questionnaire, the Mini Mental State Examination (MMSE) was scored and any falls were recorded over a period of 12 months. Posturography was measured with a force platform and eye movements were measured by video-oculography.

Results: In the majority of the elderly, vestibular abnormalities were found, such as reduced vestibulo-ocular reflex gain 6/38, spontaneous nystagmus 5/38, gaze deviation nystagmus 5/38, head shaking nystagmus 9/38, pathologic head thrust test 10/38, and positional nystagmus 17/38. Posturography demonstrated two major findings: the body support area was limited and the use of vision for postural control was reduced. In principal component analysis of the vertigo, four major factors described elements of failure in the vestibular and other systems important to maintenance of balance: episodic vertigo, postural instability, multisystem failure (frail) and presyncopal imbalance. These four factors were associated in different degrees to vestibular abnormalities and falls. During the follow-up period, in 19 elderly (19/38), one or more falls were recorded.

Conclusions: Progressive loss of balance in the aged, or “presbyequilibrium,” is a complex and incompletely understood process involving vestibular, oculomotor, visual acuity, proprioception, motor, organ system and metabolic weaknesses and disorders. These factors provide a potential basis for streamlining diagnostic evaluations and aiding in planning for effective therapy. In oldest old, these problems are magnified, increasing the need for additional expertise in their care, which may be met by training specialized healthcare staff.

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INTRODUCTION

Dizziness ranks among one of the most common complaints in medicine, affecting in some forms approximately 40% of the general population (1). It is especially prevalent in the aging population (2). In a cohort study in Gothenburg, the daily occurrence of balance problems, with or without dizziness, was present in 33% among elderly at age 70, and increased to 50% at 80 years or more (3).

The elderly understand and describe their dizziness in many ways (3) and often tend to under-report their symptoms (4). They commonly use various non-specific terms to describe their complaints of balance disorders, such as vertigo, general unsteadiness, dizziness, lightheadedness, fainting, or other illusory sensations as indications of medically specific symptoms of true vertigo. In addition, fear of falling, gait disorders, postural mismatch or oscillopsia may also be an expression of dizziness. Primary care clinicians and geriatricians commonly underdiagnose or misdiagnose dizziness and vertigo in the elderly (5). In a study by Lawson et al. of 59 patients with Benign Paroxysmal Positional Vertigo (BPPV), 31 (59%) were referred to Fall and Syncope Unit instead of ENT (6). The authors concluded that diagnosing BPPV in elderly may be difficult, particularly as this group frequently has more than one type
of dizziness symptoms, sometimes including vertigo, postural dizziness (raising the suspicion of orthostatic hypotension), and even symptoms from multiple co-morbidities and coexisting cardiovascular disorders.

Obtaining an accurate history is of utmost importance when searching for the etiology of disequilibrium complaints, but it is often difficult to understand exactly what a patient is experiencing. In the literature, the terms “dizziness” and “vertigo” suggest some link to the sites of origin of symptoms, non-specific dizziness tending to be associated with non-vestibular sites and vertigo generally related to the vestibular (mostly semicircular canal) system. Generalized imbalance symptoms and misperceptions of movements have been less specifically related to the vestibulo-spinal system or central motor control functions (7). These distinctions may not be entirely justified in the elderly, as there is a poor connection between vestibular findings and symptoms (7). The elderly often under-perceive or under-report true vertigo (8). As there will be unreliability in the reporting of disequilibrium complaints in the elderly, efforts have been made to improve the sensitivity and specificity of vestibular testing to aid in the diagnostic process. However, there are only limited data on vestibular findings in the elderly (9) and it is especially noted that there are no reports of such findings in the oldest old.

BPPV is a common cause of dizziness and is probably quite common in the elderly. It rarely occurs in children (10) but it is more common in older age groups. It has been proposed that as much as 50% of all dizziness in the elderly is due to BPPV (11). In one study, 9% of a group of urban-dwelling elders were found to have undiagnosed BPPV (4).

The purpose of the present study was to evaluate vestibular findings among the oldest old and relate findings to case histories. We hypothesized that the majority of our subjects would have vestibular dysfunction and most commonly suffer from positional vertigo, and that the vestibular deficit is also “manifested” in limited range of postural confidence area.

METHODS

Subjects
We performed a study of institutionalized oldest old subjects living in the Koukkuniemi elderly people’s home in the city of Tampere which, during the study period, housed 869 elderly persons. The nursing staff selected two or three participants from every ward, from which 38 elderly were asked to participate in the clinical study. Inclusion criteria were that subjects could be physical fit enough to raise themselves from the chair without assistance and were able to follow instructions. The City of Tampere institutional review board approved the study protocol. The mean age of subjects was 88.8 years, range 80-103 years. The study group included 31 women and 7 men. Subjects were followed for 12 months and their fall rate was evaluated. After 12 months, 32 were alive and 6 had died.

Data collection
Subjects were interviewed by means of a structured oto-neurological questionnaire to obtain uniform and detailed histories and symptoms of vertigo from each elderly person (12). When necessary, subjects’ interviews were confirmed or augmented from interviews with their personal nurses. Details of their medical diseases and data concerning falls were retrieved from individual medical charts. Nurses responsible were interviewed, to aid in determining the etiology of each fall.

The features of dizziness and vertigo were explored to categorize symptoms expressed by subjects into consistent and more precisely defined terms. Dizziness and vertigo were broken down in more detail as rotatory vertigo, floating sensation, movement instability, tendency and fear of falling, sudden loss of balance, and syncope. Some related symptoms, such as feeling of unreality, loss of vitality and reduced mobility were also queried. The occurrence of vertigo, duration of spells, and provoking factors such as movements of the head, body position, physical straining and possible neurological disorders, were checked. Subjects’ limitation of activities due to symptoms was rated on a five-step scale between “no interference with activities” to “full bed rest.” Symptoms of hearing loss and associated symptoms, such as nausea or vomiting, were queried.

The Mini Mental Status Examination (MMSE) score measures cognitive ability (attention, memory, language, calculations) with a maximum score of 30; 24 and under indicate some impairment (13).

Video-oculography (VOG)
Both eyes were measured independently in commercially available video-oculography (Micromedical Technologies, Inc. Chatham, Illinois, USA). In the test, eyes were covered by transparent video-goggles. Subjects could visualize their surroundings and fix their gaze on objects. Their eyes were illuminated with infrared lamps within the video goggles for presentation of a video monitor. The video-oculography (VOG) signal was sampled at a frequency of 25 Hz and fed into a portable computer. Internal algorithms calculated the position and movement of the iris in order to quantify eye movements.

The VOG was calibrated with a light bar placed 1.2 m in front of the subject, covering a visual field of 40 degrees. The light bar consisted of LEDs illuminated by the program, and the calibration was made with alternating saccades at 20 degrees of visual angle.

Spontaneous nystagmus was recorded during a 45-s trial in the dark (video goggles covered) by asking subjects to look forward. Gaze deviation nystagmus was thereafter recorded by asking subjects to keep the gaze first to the far right for 20 s and then to the far left. The vestibulo-ocular reflex (VOR) was recorded first in light and then with eyes covered. Subjects maintained their gaze fixed forward.
and on the midline, while the examiner rotated the head about 20 degrees back and forth at a rate of 1 Hz for 15 sec. Head-shaking nystagmus was achieved by subjects shaking their heads rapidly on both sides 20 times with eyes covered. Head thrust was recorded by turning the head quickly from each side to the middle line with eyes covered. Saccades were recorded by asking subjects to stare at a light spot and follow it as rapidly as they could when the bar was jumping from 5 to 40 degrees visual angle in pseudo-random order. Smooth pursuits were measured by asking subjects to stare at a light spot which moved sinusoidally in the bar.

Positional manoeuvres were conducted with subjects sitting on a bed and asking them to hold tightly onto the wrists of the examiner. Subjects were then brought rapidly to a lateral decubitus position with the head tilted 45 degrees to the side (toward the bed). This position was maintained for up to five minutes or until the nystagmus ceased. Thereafter, subjects were raised, passing through the sitting position, and brought to the lateral decubitus position on the contralateral side, with the head tilted 45 degrees toward the bed. The test was conducted with eyes covered and any nystagmus was recorded. Also noted was whether the test had provoked vertigo.

The oculomotor responses to the test were evaluated visually by spontaneous nystagmus and head thrust test and with software analysing voluntary eye movements to calculate reaction time, accuracy and velocity of saccades, and gain of smooth pursuit. Due to problems with binocular vision caused by aging, only the reaction time of saccades was used in calculations. Pathological outcomes were considered to be the presence of spontaneous or gaze nystagmus, the nystagmus produced by the head-shaking test, and abnormal saccades from head thrust tests, according to Halmaqui. In VOR testing, deviation of the eyes from the central position to the side was scored as abnormal.

**Posturography**

Force platform posturography technique was used (14, 15). Postural performance ranges were determined for antero-posterior direction and for lateral direction. Postural stability was evaluated in visual and non-visual conditions. Sway velocity and maximum amplitude of body sway were used as outcome variables. Romberg’s quotient was calculated (mm/s).

**Statistics**

Results on vertigo were analysed by factorial analysis with varimax rotations. Associations were evaluated with correlation analysis by Pearson’s test for continuous variables and Kendall’s tau analysis for class variables. Modeling of factors describing presbyequilibrium was made by linear regression analysis. The Mann-Whitney U-test was used to assess differences between binary variables.

**RESULTS**

**Clinical symptoms and MMSE**

In clinical evaluation, three subjects had cerebellar ataxia, one had undergone craniotomy after trauma, and one had cerebrospinal shunt (Table 1). Five subjects had Parkinson’s disease. In six subjects, visual problems caused impairment in voluntary eye movement tests, due to disparity of gaze nystagmus (1), cataract (2), parafoveal fixation (1), hemianopsia (1) and/or strabismus (1). Due to frailty and/or dementia, complete positional and vestibular testing could not be carried out in 5 subjects.

Subjects were followed-up for 12 months. One or more falls were recorded for 19 of them. In 19 no falls were recorded. After a 12-month follow-up, 6 subjects had died and 32 were living. Their mean MMSE scores during the study were 20.5, range 6-30. Fifteen subjects had MMSE scores <24, and 23 had 24 or better.

**Vertigo, dizziness and balance symptoms**

Of the 38 subjects, 26 (68%) had dizziness or vertigo in their recent history, the nature of which was further explored with subsequent specific questions. Most subjects had more than one type of complaint (Fig. 1).

**Table 1 - Clinical signs among elderly subjects.**

<table>
<thead>
<tr>
<th>Symptom combinations</th>
<th>N. elderly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parkinson’s disease</td>
<td>5</td>
</tr>
<tr>
<td>Cerebellar degeneration</td>
<td>3</td>
</tr>
<tr>
<td>Craniotomy or shunt</td>
<td>2</td>
</tr>
<tr>
<td>Visual impairment</td>
<td>6</td>
</tr>
</tbody>
</table>

**Fig. 1 - Prevalence of vertigo and its symptoms.**

1=No Vertigo; 2=Poor Postural Stability; 3=Rotation+Floating+Poor Postural Stability; 4=Syncope with other symptoms (rotation, floating, poor postural stability); 5=Rotation; 6=Rotation+Floating; 7=Rotation+Poor Postural Stability; 8=Syncope. Numbers within bars indicate number of subjects.
Vertigo was described as constant in 11 subjects, episodic in 12, and both constant and episodic in three. The duration of episodic attacks (n=15) was few seconds (1-5 sec) in four subjects, up to 5 minutes in seven, and up to 4 hours in four. The intensity of attacks varied from slight to severe. In ten subjects, the attacks were so severe that they either had to rest (five) or symptoms continued despite resting (five). Head movement was the most common provocative factor (Table 2).

**Factorial analysis**

We performed principal component analysis (Varimax rotation) to identify internal associations of vertigo, dizziness and impaired balance. In this analysis, four major components were identified, which described 75% of the data. The four components were further classified by their characteristics and named to describe their component of “presbyequilibrium”. Associations are listed in Table 3.

The factors and their components were:

1. **Episodic presbyvertigo syndrome (Factor 1)** contained characteristics indicating “episodic vestibular changes”. Subjects had vertigo provoked by physical strain or activity, often accompanied by nausea during the attack. Subjects suffered from poor postural stability (instability, combined with subjective feeling of falling) and tended to experience episodes of sudden instability. BPPV in vestibular testing was correlated with episodic presbyvertigo syndrome (r=0.383, p=0.035). We used a linear regression model to search for variables associated with Factor 1. Orthostatism (p=0.004), vertigo during rising (p=0.074) and falls (p=0.001) explained 53.7% of the variation of Factor 1. The model was significant (p=0.001).

2. **Postural presbyequilibrium (Factor 2)**. Subjects experienced postural imbalance, and gravity-dependent positional changes could provoke attacks. BPPV tended to correlate negatively with this category (r=-0.279, p=0.060). In modeling explanatory items for factor 2, falls was the only factor included in the model and explained 12.3% of the variability.

3. **Frail syndrome (Factor 3)** was characterized by poor muscle strength and coordination, and the need for assistance in movements. Subjects preferred to use their hands to assist themselves when rising from a chair and used supporting devices for walking. They reported more continuous dizziness, associated with subjective feelings of falling. In modeling explanatory items for Factor 3, a linear regression model was significant, consisting of reduced VOR (p=0.001), vertical nystagmus (p=0.006) and gaze nystagmus (p=0.059), and the model explained 43.8% of the variability.

4. **Autonomic vertigo syndrome (Factor 4)** was characterized by episodes suggesting autonomic compro-
mise, including syncope, near-syncope or a floating sensation, which were all provoked by positional changes. These subjects fell more than eight times during the 12-month follow-up. Syncopal presbyequilibrium tended to correlate with the falls (r=0.252, p=0.067). In modeling Factor 4, a model consisting of low MMSE score (p=0.059) and smooth pursuit deficit (p=0.054) was significant, and explained 23.1% of the variability.

**Video-oculography results**

Positioning testing for benign positional vertigo was studied in 31 subjects. The test could not be carried out in 5 subjects, due to their current health status. Despite extreme care to handle each elderly subject gently during positional testing, one subject lost consciousness for a few seconds, and two vomited. Seventeen (17/31) had positional nystagmus. The presence of nystagmus in positioning testing was correlated with a sensation of vertigo (r=0.471, p=0.007) except for 4 out of 17 subjects who had nystagmus but did not report any vertigo and 3 out of 17 without nystagmus who reported moderate or severe vertigo. Three subjects had positional nystagmus in bilateral positions. Positional nystagmus was further classified either as peripheral or central, based on abnormalities in oculomotor testing (vertical nystagmus, gaze deviation nystagmus) and on case-histories of brain diseases or disorders (CSF drain, infarction, cerebellar damage). Eight subjects were classified as having the central type of positional vertigo. Nine were classified as BPPV, representing the peripheral type of vertigo (Table 3).

In analysing the internal dependencies of VOG variables, nystagmus in positioning testing correlated significantly with reduction of gain in VOR (r=0.376, p=0.037) and with gaze deviation nystagmus (r=0.361, p=0.046). Peripheral positional vertigo was accompanied by slight to moderate vertigo sensation (r=0.401, p=0.025), but central positional vertigo was not.

Spontaneous nystagmus was most commonly of the vertical down-beating type (4 out of 5). Gaze nystagmus was correlated with reduction in VOR (r=0.670, p<0.001). In addition, gaze deviation nystagmus was correlated with cerebellar lesions (r=0.716, p<0.001). A reduction in smooth pursuit was correlated with prolonged latency of saccades in the random saccade test (r=0.583, p<0.001).

Neither age nor gender correlated with any of the VOG variables; nor did any of the histories of balance disorders, tendency to fall, instability, vertigo or dizziness correlate with VOG variables. Poor mobility was correlated with positional nystagmus of central type (r=0.457, p=0.010).

Central positional nystagmus was correlated with vestibular frail syndrome (r=0.469, p=0.008), and BPPV with episodic presbyvertigo syndrome (r=0.323, p=0.035).

MMSE scores were classified to normal (≥24) and reduced (<24), and were lower in subjects with vertical nystagmus (r=0.392, p=0.024) and central positioning nystagmus (r=0.383 p=0.012). In other VOG measurements no significant differences were observed. Nevertheless, in the Mann-Whitney U-test, those with low MMSE scores had significantly reduced quality of life (p=0.030) and experienced lower vitality and energy (p=0.027). No differences in mortality or accidental falls were observed between the MMSE groups.

**Measurement of postural stability**

The posturography could not be performed to 12 subjects due to their current health. Both visual and non-visual conditions were measured, except in one subject in whom non-visual conditions could not be measured (Table 4). The mean Romberg quotient in sway velocity (mm/s) was 1.27 (SD 0.29) and in sway maximum amplitude (cm) 1.34 (SD 0.33). These values are low, indicating poor use of vision for postural stabilization among the oldest old. These with vertigo in positioning testing showed a low Romberg quotient (r=0.416, p=0.035 for sway velocity,}

### Table 4 - Abnormal vestibular and oculomotor responses in VOG among oldest old.

<table>
<thead>
<tr>
<th>Test/dysfunction</th>
<th>Pathological</th>
<th>Normal</th>
<th>N. tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous nystagmus</td>
<td>5</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>Positional nystagmus in Dix Hallpike</td>
<td>17</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Vertigo in positional test</td>
<td>16</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>Gaze nystagmus</td>
<td>5</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>VOR</td>
<td>6</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>Head-shaking nystagmus</td>
<td>9</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>Refixation saccades in head thrust test</td>
<td>10</td>
<td>23</td>
<td>33</td>
</tr>
<tr>
<td>Saccades</td>
<td>26</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Smooth pursuit</td>
<td>17</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

VOR: vestibulo-ocular reflex at 1 Hz.
and \( r=0.502, p=0.011 \) for sway maximum amplitude.

The postural limits and leaning tests could only be carried out in 8 subjects, as these tasks were even more demanding. The antero-posterior range of postural stability was on average 2.0 cm (median value 1.2 cm, SD 2.4 cm) and in lateral direction 1.3 cm (median value 1.2 cm, SD 2.9 cm). The results indicated limitation of the postural confidence area in the subjects. The MMSE scores were correlated with poor postural control on the force platform \((r=0.529, p=0.003)\).

**DISCUSSION**

Deterioration of balance is an insidious process, starting in late middle age (16). Most often, the elderly cope with this deterioration by using avoidance strategies, instead of re-challenging their balance in complex environmental demands. In this study, symptoms of vertigo and dizziness were prevalent in 68% of the institutionalized elderly. Noteworthy was the fact that the nursing staff did not address this problem with balance exercises or rehabilitation. Although several studies have demonstrated the association of dizziness and poor balance with falls, it is often difficult to determine the underlying mechanism of poor balance and vestibular symptoms in the elderly (17). We demonstrate in this study that in aging, there is a powerful limitation of the postural confidence area, and the oldest old do not use sight adequately to control their postural stability. We also demonstrate that a significant proportion of the elderly have positional nystagmus due to other vestibular and oculomotor abnormalities. Nevertheless, no single item in the case histories reliably predicts fallers from non-fallers, nor could we discriminate, on the basis of posturography or oculomotor testing, subjects with a history of falls from those without.

**Symptoms of vertigo and dizziness**

The evaluation of dizziness in geriatric patients is often a frustrating experience for the physician. This may be because of difficulties in sorting through the multiple symptoms that geriatric patients often have; the lack of specific physical examination findings or diagnostic tests for balance disorders; and the wide range of potential causes of balance disorders. Patients are often empirically given vestibular sedatives, which have significant side-effects in this age group. They may simply be dismissed as being old. Alternatively, they may undergo exhaustive and expensive non-directed medical and imaging studies, together with serial consultant opinions.

We further classified the balance-related symptoms by factorial analysis and could observe four different entities describing the “presbyequilibrium”. The factors showed different association with VOG and posturography measurements, and these too may help to direct physician toward the underlying pathology. Episodic presbyequilibrium (Factor 1) contained characteristics indicating “episodic vestibular changes”. Subjects had vertigo provoked by physical strain or activity, often accompanied by nausea during the attack. Subjects suffered from poor postural stability (instability, combined with subjective feelings of falling, and tended to experience episodes of sudden instability). In postural presbyequilibrium (Factor 2), subjects experienced postural imbalance and rotational vertigo attacks that could occur suddenly and of short duration more than twice a month. The positional changes could provoke the attacks. The frail presbyequilibrium (Factor 3) was characterized by poor muscle strength and coordination, and the need for assistance in movements. Subjects preferred to use their hands to assist themselves when rising from a chair and used supporting devices for walking. This group was noteworthy for continuous dizziness associated with subjective feelings of falling. The symptom entity described by VOR deficit correlated with this group. Lastly, syncopal presbyequilibrium (Factor 4) was characterized by episodes of syncope, nearsyncope or a floating sensation and could be provoked by positional changes. It was associated with poor memory and defective smooth pursuit. Subjects with syncopal presbyequilibrium fell more than eight times during the 12-month follow-up period.

These four different factors carry out important messages for physicians treating or examining the elderly. The frail presbyequilibrium group needs vestibular rehabilitation with muscle strength training to prevent falls. The syncopal presbyequilibrium group needs medical attention for diagnosis and treatment. Neurocardiogenic syndrome (NCS) is an important entity to consider in the advanced aged population, since it may be the reason for their poor balance performance and falls. Episodic and postural presbyequilibrium needs vestibular and medical work-up to reveal the pathophysiological mechanisms and to allow proper vestibular treatment in those who will benefit from it. Epidemiologically, problems with vertigo, dizziness and postural imbalance are so vast in the elderly that geriatricians and otologists may be insufficient in numbers to be able to help this population properly. With the rapid growth in the geriatric population, it would be beneficial to create a new type of specialized vestibular healthcare professional. We deliberately propose that these specially trained individuals may best be termed “geriatric vestibular nurses”, as they must be capable of taking careful vestibular case histories and performing balance and vestibular testing, including posturography and video-oculography.

**VOG findings**

We observed that the vestibular symptoms did not always accompany with nystagmus in the positioning test. Our subjects could have vigorous nystagmus without vertigo or dizziness, or experience symptoms without any
nystagmus in the test thus confirming previous findings that the elderly with BPPV often do not report the classically described symptoms (6). Lawson et al. demonstrated that, when compared with younger patients with BPPV, the elderly were significantly more likely to describe dizziness with postural changes (40% vs 14%) and less likely to describe rotatory vertigo (40% vs 89%) (6). Our results confirm the finding that making a diagnosis of BPPV in older people may be difficult, particularly as this group frequently has more than one type of dizziness: postural dizziness symptoms (raising the suspicion of orthostatic hypotension) and multiple co-morbidities and co-existing cardiovascular diagnoses. Oghalai et al. demonstrated in elderly care centre that not one of the elderly identified with BPPV had reported dizziness to their primary care doctors (4). Lawson et al. also reported that the elderly group had no previous provisional diagnosis of BPPV or positional vertigo made by their primary care practitioners (6).

As far as we know, there are no previous studies in which posturography and VOG have been recorded among oldest old. In posturography, the most striking finding was the limited use of the confidence area applied in the support of balance in the elderly. As this range was so limited (about 5 cm²), there must be many situations during the daily activities in which the balance will fall outside this confidence area, forcing them to seek for external support to prevent a fall. In our opinion, one of the key rehabilitation goals in the elderly is to widen their narrow postural confidence area. Kerber et al. (7) evaluated postural responses in elderly subjects and found an association of poor balance, accidental falls, with poor outcomes of posturographic measurements. They regarded postural imbalance as a key factor in explaining accidental falls.

In elderly subjects, Bloom and Katsarkas (2) used the presence of a sensation of spinning and the absence of a sensation of lightheadedness in order to predict that an elderly has BPPV. This may be a useful screening tool to evaluate BPPV during routine work-up of all elderly patients. In our study, absence of vertigo with nystagmus and presence of vertigo without nystagmus indicate that this method may not be accurate in the oldest old.

Once a balance disorder is identified, it is often a challenge to treat. The repositioning maneuver has a good success rate in curing BPPV (18). Exercises designed to habituate the response have also been shown to hasten recovery time (19, 20). Early recognition and treatment of BPPV in these patients may improve functioning and quality of life, although further prospective studies are warranted (4).

CONCLUSIONS

Vertigo and dizziness among the elderly is a complex and common symptom, to which the failure of many possible systems may contribute. Vestibular control may be disturbed by various central or peripheral mechanisms, which are categorized into four main paradigms, to make etiology easier to identify.

Positional vertigo was prevalent in 55% of institutionalized elderly persons. In the majority, specific vestibular abnormalities were found, consisting of reduced VOR gain, spontaneous nystagmus, and others. The posturography demonstrated two major findings: the postural confidence area was severely limited to about 5 cm, and the use of vision in assisting postural control was reduced. We used factorial analysis to further classify the balance related symptoms and could observe four different entities describing the “presbyequilibrium”. These factors showed different association with VOG and posturography measurements, and may aid in describing underlying pathology. The range of problems with vertigo, dizziness and postural imbalance is so vast in the elderly the geriatricians and otologists may not be capable of handling it. Therefore, a new personal category of specialized nursing staff should be trained. We provocatively name the groups as “geriatric nurses”, as they must be capable of taking careful vestibular case histories and performing balance and vestibular testing, including posturography and video-oculography. In fall prevention, this group may guide the elderly toward different types of rehabilitation programs or medical examinations, as indicated.

ACKNOWLEDGEMENTS

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REFERENCES


Postural stability and quality of life after guided and self-training among older adults residing in an institutional setting

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Purpose: To evaluate whether rehabilitation of muscle force or balance improves postural stability and quality of life (QoL), and whether self-administered training is comparable with guided training among older adults residing in an institutional setting.

Patients and methods: A randomized, prospective intervention study was undertaken among 55 elderly patients. Three intervention groups were evaluated: a muscle force training group; a balance and muscle force training group; and a self-administered training group. Each group underwent 1-hour-long training sessions, twice a week, for 3 months. Postural stability was measured at onset, after 3 months, and after 6 months. Time-domain-dependent body sway variables were calculated. The fall rate was evaluated for 3 years. General health related quality of life (HRQoL) was measured with a 15D instrument. Postural stability was used as a primary outcome, with QoL and falls used as secondary outcomes.

Results: Muscle force trainees were able to undertake training, progressing towards more strenuous exercises. In posturography, the number of spiky oscillations was reduced after training, and stationary fields of torque moments of the ankle increased, providing better postural stability in all groups; in particular, the zero crossing rate of weight signal and the number of low variability episodes in the stabilogram were improved after training. While no difference was found between different training groups in posturography outcomes, a reduction of fall rate was significant in only the guided training groups. A significant part of the variability of the QoL could be explained by the posturography outcome (46%). However, the outcome of training was associated with a reduced QoL.

Conclusion: Even moderate or severely demented residents could do exercises in five-person groups under the supervision of a physiotherapist. An improvement in postural stability was observed in all training groups, indicating that even self-administered training could be beneficial. Posturography outcome indicated that training alters the postural strategy by reducing the oscillatory fluctuations of body sway signal. However, only guided training tended to reduce falls. Short training intervention programs may decrease QoL by changing the elderly’s daily routine and making it more active and exhausting.

Keywords: force and balance training, falls, time-domain body sway analysis, psychological consequences

Introduction

Accidental falls are one of the leading causes of death among the elderly population, surpassing even those due to car accidents.1 Among people aged 85 years and older, one out of five fatal falls occurs in a nursing home.2 Rubenstein et al3 reviewed such falls and showed that the mean incidence of falls in nursing homes is 1.5 falls per bed per year (range: 0.2–3.6 falls). Because of the high frequency...
of recurrent falls in nursing homes, the likelihood of sustaining an injurious fall is substantial. In addition, falls reduce quality of life (QoL). Posturography has been used to objectively screen and predict those elderly who are liable to fall. Era et al. studied 7,979 subjects using posturography. Measurements showed a decline in balance functions with advancing age, starting from about 60 years. Rasku et al. demonstrated that the decline of postural stability continued to deteriorate up to 90 years of age; by careful evaluation of a stabilogram, the age of subjects could be predicted with an accuracy of 5 years. Kerber et al. demonstrated an association of poor balance and accidental falls with the outcomes of posturographic measurements. They regarded postural imbalance as a key factor for explaining accidental falls. However, the clinical value of posturography is still controversial in assessing the elderly’s likelihood of falling. One of the main problems in the use of posturography is that there is no standard for measurement or agreement on the variables to be analyzed. The richness of existing variables calculated from stabilogram signals contains useful information on upright stance, but may also blur the data by unnecessarily increasing the dimension of feature space, thus making balance analysis more complicated.

Rehabilitation may improve postural stability and prevent falls when medical therapy has reached its limits, but in older adults residing in an institutional setting there is insufficient evidence of any benefit of fall interventions. Recently Neyens et al. performed an extensive literature survey on interventions to prevent falls in long-term care facilities. They concluded that the evidence is inconclusive for multifaceted and single interventions in long-term care facilities. Most of the reviewed studies did not find a significant positive effect on fall incidents. However, their data supports the conclusion that multifactorial interventions in long-term care populations seems more likely to be beneficial (as also indicated by Gillespie et al.) among older people living in a community setting. A careful approach to fall prevention is needed as programs to prevent falls in these settings may be ineffective or may even have adverse effects. Recently, we demonstrated that rehabilitation with balance and muscle force training reduced the number of accidental falls in older people living in a community setting, and even in residents with dementia. The aim of the present study is to evaluate the effect of muscle force training, balance training, and self-training on several time-domain variables retrieved from stabilograms. A further aim was to explore the consequences of training on the general HRQoL.

Methods
The older adults of the Koukkuniemi residential facility
The study was carried out in a residential facility in Koukkuniemi, Tampere, Finland. The home housed 869 older adults during the study period. The majority of the residents needed support for moving, or suffered moderate to severe dementia. The criteria for inclusion in the study were (a) the subject’s ability to raise herself/himself from a chair without using their hands or arms for support, and (b) their willingness to participate in the intervention. Of the 869 residents, 156 met the criteria and 59 (15 male and 44 female) volunteered to take part in the study. The City of Tampere’s institutional review board approved the study protocol. The participants were randomly assigned to three groups – one with muscle force training, one with balance and muscle force training, and one with self-administered training (with instructions) on the ward under the supervision of a personal geriatric nurse. Four of the participants died before baseline testing and commencement of the training, and thus the groups consisted of 18 participants with muscle force training, 19 with self-administered training, and 18 with balance and muscle force training (Table 1).

Data collection
In order to define the case history concerning vertigo, balance problems, and general health, a standardized questionnaire was administered that consisted of 98 questions about the resident’s symptoms, medical history, and medication. The character of balance problems and dizziness was explored to categorize the often vague and imprecise symptoms expressed by the subjects into consistent and more precisely defined terms. Balance problems and dizziness were broken down into more detail as rotatory vertigo, dizziness, movement instability, fear of falling, sudden loss of balance, light headiness, and a floating sensation and/or black-out. In addition, some related symptoms such as a feeling of unreality, loss of vitality, nervousness, and reduced mobility were queried. The subjects were rated for limitation in activities due to symptoms. Finally, the effect of balance problems, vertigo, or dizziness on the subjects’ everyday life was evaluated. In gathering the data, one of the authors (ET) interviewed the participants and, when necessary, used the participant’s personal nurses as proxies.

The Mini Mental Status Examination (MMSE) measures cognitive ability (attention, memory, language, and calculations) and has a maximum score of 30. For MMSE,
Table 1 Characteristics and number of elderly in each exercise training group

<table>
<thead>
<tr>
<th></th>
<th>Muscle n = 18</th>
<th>Balance and muscle n = 18</th>
<th>Self-administered n = 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>84.7 (SD = 5.5)</td>
<td>85 (SD = 4.2)</td>
<td>86.1 (SD = 7.3)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
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<td>16</td>
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<td>2</td>
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</tr>
<tr>
<td>Alcohol</td>
<td></td>
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<tr>
<td>No alcohol</td>
<td>16</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Under 4 doses</td>
<td>2</td>
<td>1</td>
<td>0</td>
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<tr>
<td>per week</td>
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<tr>
<td>5–9 doses</td>
<td>0</td>
<td>0</td>
<td>3</td>
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<tr>
<td>per week</td>
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<tr>
<td>10–20 doses</td>
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<td>0</td>
<td>1</td>
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<td>per week</td>
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<tr>
<td>Medications</td>
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<td>14</td>
<td>12</td>
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<tr>
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<td>14</td>
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<td>12</td>
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<td>10</td>
<td>13</td>
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<tr>
<td>Medication</td>
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<td></td>
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<tr>
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<tr>
<td>MCC</td>
<td>6</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Hypertension</td>
<td>12</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Kidney dysfunction</td>
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<td>0</td>
<td>1</td>
</tr>
<tr>
<td>DM I &amp; II</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Hypothyreosis</td>
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<td>2</td>
<td>4</td>
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<tr>
<td>MMSE</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>19 (11–29)</td>
<td>19 (2–29)</td>
<td>21 (2–29)</td>
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<td>MMSE 27–30</td>
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<td>3</td>
<td>5</td>
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<td>MMSE 21–26</td>
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<td>7</td>
<td>5</td>
</tr>
<tr>
<td>MMSE 11–20</td>
<td>10</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>MMSE 0–10</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Hearing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At 1000 Hz</td>
<td>33 (15–45)</td>
<td>31 (20–65)</td>
<td>32 (15–55)</td>
</tr>
</tbody>
</table>

Notes: Age, sex, alcohol consumption, medications, diseases, MMSE score and hearing level at 1000 Hz of the right ear at the beginning of the test (mean and range are shown). None of the measures differed statistically between groups.

Abbreviations: SD, standard deviation; NSAIDs, non-steroidal anti-inflammatory drugs; MCC, myocardial congestion; DM I & II, diabetes mellitus types 1 and 2; MMSE, Mini Mental Status Examination.

24 is the normal limit; anything lower indicates some impairment.18

The 15D is a widely used method to assess general HRQoL; it consists of 15 questions, each graded to 5 levels. Thus the person has 15 possibilities with which to reply, and each reply to a question is weighted with a calculation to provide a final score. The 15D questions concern sensory functions and mobility, the participant’s ability to perform regular day-to-day tasks, and their perceptions about their capabilities and limitations.19 The final score is between 0 and 1, where 0 indicates a condition akin to death and 1 a full, complaint-free life. The instrument is designed to establish the degree to which patients are content with their lives and abilities. For example, the question about walking ability is rated as follows: 0 = I can walk normally; 1 = I can walk with little difficulty; 2 = I can walk with notable difficulties; 3 = I can only walk a little; and 4 = I am unable to walk. As the participants were living in a residential home, we did not use the sex question available in the instrument. The QoL was investigated both at the beginning of training and after the 3-month training period had ended.

Training

Training took place in groups of five under the supervision of physiotherapists. Each day, two trained physiotherapists controlled the exercise intensity and adjusted it to the trainee’s capacity. In the self-training groups, personal nurses on the ward provided stimulation and encouraged the participants to keep up with their self-guided training tasks twice a week, for around 1 hour at a time. The self-guided training took place based on written instructions provided by the physiotherapists. Exercises were scheduled twice a week, 1 hour at a time, for 26 sessions over 13 weeks. We then followed the trainees over 3 years by recording their falls and the reasons for their falls during this period. Fall data was collected using fall questionnaires obtained from the ward nurses. Every fall was documented and efforts were made to find out the reasons and circumstances leading to the fall.

In muscle force training, the exercises focused on increasing the muscle strength of the hip and other postural muscles, with exercises becoming more strenuous over time. In sessions 1–5, the exercises started with warm-up training lasting 10 minutes. This included stretching each leg in the sitting position, standing up exercises, squats (bending deeply at the knees) to standing position beside parallel bars, three repeats of side steps to the left and right, standing on tiptoes, and alternatingly raising both knees with the support of a parallel bar. From the sixth training session onwards, 1.2 kg weights were fixed to the ankles. From the ninth training session onward, whilst standing, exercises included knee raising and extension, adduction and abduction of the lower limbs on training equipment with extra resistance, squat to standing, and exercises on a stepper board. The exercises were carried out with weights applied and repeated ten times, which was successively increased during each session to 20 times with two repetitions. From the 19th exercise session onwards, training to walk up a staircase was added.
The balance and muscle force training aimed to increase a combination of strength, flexibility, and balance training. It started with walking on a model trace painted on the floor, shifting weight from one leg to the other, walking backwards, tandem stance training, and standing with feet together and eyes closed. From the third session onwards, we added moving by turning and twisting and walking with a beanbag on the head. From the ninth session onwards, we added stepping exercise, blind walking in parallel bars with hindrances on the support base, blind walking straight, and a bean bag stretching exercise (from squat to tiptoe). From exercise 18 onwards, a trampoline, balance board, ball bouncing, ball throwing and catching, walking on a line beside the parallel bar, and walking while turning the head side to side and head nodding were added. The muscle force training was similar to that of the muscle force group, but weights were not increased.

The self-administered training consisted of three exercises; in the sitting position there was the stretching of each leg and raises from the chair, and crouching and rising were conducted from the standing position. Instructions were given in written form and were supervised twice a week by geriatric nurses on the ward.

**Posturography**

Posturography was carried out before training, immediately after training, and 6 months after commencing the training. Posturography measures vertical forces on the force platform surface. The center point of force on the platform surface records the movement of the body’s center point of mass projecting on the platform (body sway). The weight signal of the platform measures corrective forces made by the person when adjusting posture. We used a custom-made force platform that measured vertical force distribution over the platform surface. Analysis of the data was collected on a stance lasting 15 seconds. The subjects were asked to close their eyes and instructed to keep their hands on their chest, lock their knee joints, and stand as stably as they could. The sampling frequency of the force platform was 50 Hz. Two of the signal components in the stabilogram give the location of the force reaction under the subject’s feet in mediolateral (x) and anterior-posterior (y) directions in each sample (t). The third component of the stabilogram provides the magnitude of force reaction acting on the force platform in respective sampling instants. This signal also outlines the mass of the subject; although the subject’s mass remains constant, the applied weight changes are due to muscle forces exerted in efforts to control posture.

To remove the effect of transition error and, to give the subject some time to become accustomed to the test, we removed 150 samples from the beginning of the filtered stabilograms. After preprocessing, the lengths of stabilograms amounted to 600 samples for an average of 12 seconds. We removed the mean values of the stabilogram’s positional components before further processing.

**Variables**

In the present study we selected eight time-domain variables which had the greatest associations between age and sex; for reference, we selected body sway velocity and Romberg’s quotient. Our selected variables and their abbreviations were the 95% confidence amplitude in anterior posterior direction C(Y) and the sway velocity of body sway (SV). The Romberg’s quotient was calculated (mm/s) from sway velocity values (SV eyes closed/SV eyes open). We calculated the mean of the absolute moment about the mediolateral axis M(MY), the area of ellipse which contained all stabilogram samples EA, the area of an ellipse which contained 95% of stabilogram samples CEA, the zero crossing rate of a stationary point in anterior-posterior direction ZCR(Y), the zero crossing rate of velocity in the mediolateral direction ZCR(VX), the critical time where an open loop control changes into a closed loop control CRI(T), and the number of samples which belong to a steady phase standing ST(N). In our statistical work, we took the natural logarithms of the variables in order to make their distributions closer to normal. ST(N) describes the number of moment signal samples that belong to a steady phase standing. The steady phases during quiet standing (ST[N]) are illustrated in Figure 1. The location of the center point of force (CPF) can be extracted directly from the preprocessed stabilogram;
Figure 1 illustrates the steady phase standing, and is marked with circles.

The signal was also composed of many low variance periods and many “spiky” periods that were indicators of rapid and frequent oscillations in posture. A moving window was ultimately slid over the entire weight signal. Figure 2 depicts the low and high variation areas and also indicates the zero crossing rate of weight. Inside the low variation areas the signal changes signs relatively frequently; however, in the “spiky” areas the signal sign does not change so often. The postural stability was evaluated in visual and nonvisual conditions. Sway velocity and maximum amplitude of body sway were used as outcome variables. The Romberg’s quotient was calculated (mm/s).

**Statistical analysis**

Differences in continuous variables between the training groups were analyzed with an analysis of variance (ANOVA) and in discrete variables with the Mann–Whitney U-test, Chi-square test, or Wilcoxon signed-rank test. In exploring associations, a linear correlation was made and evaluated using Kendall’s tau. In analyzing the posturography outcome and changes in QoL, a paired Student’s t-test was used. In searching for associations between risk factors and the posturography outcome analysis of variance (ANOVA), and in the case of binary variables, logistic regression analysis was carried out.

**Results**

Before the end of the training, six residents stopped training (four in the balance and muscle force training group; two in the muscle force training group). Their scores in the 15D instrument were significantly lower than the others (Mann–Whitney U-test, \( P = 0.032 \)); in particular, their scores were significantly lower in vigilance (\( P = 0.014 \)), depression (\( P = 0.005 \)), and anxiousness (\( P = 0.015 \)). In presbyequilibrium the participants who stopped their training had more frequent vertigo (\( P = 0.047 \)) and floating sensations (\( P = 0.033 \)).

**Effects of training on postural stability**

When inspecting the effect of training on postural stability using posturography, all groups showed significant improvements (Table 2). The muscle force training groups tended to improve most, followed by the self-training group and then the balance training group, but the differences were not statistically significant.

After training, the occurrence of “spiky” oscillations was reduced and the stationary fields of torque moment of the ankle increased, providing better stability. Postural strategy was changed in all groups so that the participants reduced their random body sway and started to oscillate around a predetermined attractor (neutral point), and tried to hold their posture without exceeding stability ranges. They did however sway to the same extent as before commencing the training when measured by means of sway velocity and area of body sway. In regard to the risk factors for falls, those

**Table 2 Posturography measurements at 3 months from training in the muscle force, self-administered, and balance training groups**

<table>
<thead>
<tr>
<th>Variable measured after 3 months of training</th>
<th>Muscle training (n = 16)</th>
<th>Self-administered (n = 18)</th>
<th>Muscle and balance training (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of body sway</td>
<td>3.6 cm² (1.2)</td>
<td>3.4 cm² (2.1)</td>
<td>27 (15.2)**</td>
</tr>
<tr>
<td>Number of low variability episodes in stabilogram</td>
<td>27 (7.3)**</td>
<td>22 (15.2)**</td>
<td>24 (26.9)</td>
</tr>
<tr>
<td>Zero crossing rate of stationary point in AP-direction</td>
<td>22 (7.2)**</td>
<td>18 (7.2)</td>
<td>19 (12.5)</td>
</tr>
<tr>
<td>Zero crossing rate of velocity signal in AP-direction</td>
<td>211 (64.4)*</td>
<td>199 (67.9)**</td>
<td>179 (49.2)</td>
</tr>
<tr>
<td>Zero crossing rate of weight signal</td>
<td>138 (61.2)**</td>
<td>90 (53.5)**</td>
<td>128 (65.4)**</td>
</tr>
<tr>
<td>Number of periods during stationary standing phases</td>
<td>162 (73)</td>
<td>168 (166)*</td>
<td>109 (164)</td>
</tr>
</tbody>
</table>

Notes: *P < 0.05, **P < 0.01, and ***P < 0.001 when compared with base line measurements. Mean and standard deviation are given. 

Abbreviation: AP, antero-posterior.
participants who indicated problems with gait and mobility had significantly worsened postural stability. Within the ANOVA analysis, a model consisting of the zero crossing rate of weight signal and the number of low variability episodes in the stabilogram was significant \( (P < 0.001) \), and explained 16.5% of the variance of problems in mobility.

**Associations with falls**
In posturography the training groups differed in Romberg’s quotient with respect to falls in ANOVA \( (P < 0.01) \). Thus, non-fallers used visual information to stabilize their balance on the force platform; however, such a positive integration of visual and vestibular influxes was not seen in fallers.

The participants with muscle force training and those with balance and muscle force training tended to have fewer falls than those with self-administered training (Table 3). The difference between the groups was statistically significant (Chi-square test, \( P = 0.02 \)) (Figure 3). However, in logistic regression analysis, only in habitual fallers did the posturography measures correlate with outcome in falls (number of low variability \( r = -0.466, P < 0.01 \); zero crossing rate of velocity signal in AP-direction \( r = 0.278, P < 0.05 \)).

There was no significant long-term effect of training on the death rate between the different groups. On average, the MMSE-index showed that global cognitive status was impaired in 29% of the study groups when training began, and in 79% after 3 years. The MMSE index neither correlated with the level of falls, training group nor the outcomes of posturography.

**QoL**
The 15D QoL was 0.8 at the beginning of training but was reduced to 0.71 as the training ended (paired Student’s \( t \)-test, \( P < 0.001 \)) and 0.73 after 6 months (paired Student’s \( t \)-test, \( P < 0.001 \)) (Figure 4). No differences were observed in 15D measures between the different training groups (Table 4). When exploring the association between the 15D instrument and the outcome of posturography in ANOVA, we found significant association between postural stability and QoL \( (F = 11.4, P < 0.001, \text{beta} -0.587) \). A model explaining 46% of the variability in the 15D QoL consisted of the critical time \( (P < 0.001, \text{beta} -0.650) \) and the zero crossing rate of the weight signal \( (P < 0.024, \text{beta} 0.344) \).

When analyzing internal factors of the 15D instrument, the mobility rating at the beginning and after training showed no significant changes. However, vitality scores significantly worsened immediately after training, but recovered after 6 months (Student’s \( t \)-test, \( P < 0.001 \)). A similar observation was seen in analyzing the activity scores (Student’s \( t \)-test, \( P < 0.05 \)) (Figure 4). Participants also felt more weary, tired, or feeble than at the beginning of training (Student’s \( t \)-test, \( P < 0.001 \)) (Figure 5). No differences were found between the training groups.

When investigating the effect of training on mood disorders and mental function, we used the depression and mental score questions. After the training period had ended, participants felt more depressed (Student’s \( t \)-test, \( P < 0.05 \)) and impaired in mental functions (Student’s \( t \)-test, \( P < 0.001 \)) than at the beginning of training; the depression scores returned to baseline levels 6 months after commencing the training (Figure 4).

**Discussion**
We compared guided balance and muscle force training with self-administered training in older adults residing in an institutional setting. The postural stability was measured with a force platform, and general HRQoL measures were used. Residents with moderate or severe dementia could perform exercises in a five person group under the supervision of a physiotherapist. Personal nurses proved to be an effective resource on the ward when stimulating and encouraging the participants to keep up with their self-guided training. When inspecting the effect of training on postural stability,
all groups showed significant improvements. The muscle force training groups tended to improve the most, followed by the self-training group and then the balance training group, although the differences were not statistically significant. Posturography revealed an improvement in postural stability and balance control strategy. The outcome of fall rates differed between the training groups; guided training was more effective than self-training. The training was associated with a reduced QoL. It is possible that the training efforts, although carefully controlled and individually tailored, proved too strenuous for the frail participants, and perhaps different protocols should be evaluated before any therapeutic recommendation can be made.

Postural stability on the force platform

In posturography, the center point of force has commonly been used to characterize the subject’s ability to control their posture. The conventional parameters used have failed to distinguish fallers from non-fallers in geriatric facilities. There are many possible explanations for this, including a shortage of optimal reference persons, that “near falls” are handled as non-falls, the stochastic nature of falls, and the shortage of descriptive parameters used in evaluation. In spite of these shortcomings however, posturography can be a useful instrument in describing the outcomes of rehabilitation. We have previously indicated that body sway is a random phenomenon in the elderly; this phenomenon contrasts with younger residents in whom body sway is predictive and seems to oscillate around an attractor. Interestingly, after 3 months of training we were able to show that participants regained the strategy to sway around an attractor. In this way they recalled their “postural memory” and could avoid falling to the outside of their stability area. In the variables analyzed with the zero crossing rate of weight signal, it is possible to detect transients in the stabilogram signal. The time delay between two zero crossings is usually small and quite constant. During the transients however, the time delay is greater. This time delay was reduced among the participants after training, and the number of zero crossing rates increased. In a time-domain, the zero crossing rate varies during measurement for reasons which are related to postural control strategy and other physical actions. The zero crossing rate strategy will tend to keep the person in proximity to the selected attractor. An improvement in postural stability was not observed in traditional measures such as the velocity of body sway or sway area; however, an improvement was noted in strategy with a move towards diminishing periods of random body oscillations. This change of strategy will thus reduce postural effort. Muscle force training is especially useful to prevent slips and falls but also improves the postural stability during quiet stance.

Rehabilitation of muscle force and balance

Preventing falls may require the selection of a population that is most likely to benefit from rehabilitation, as well as a selection of interventions. Rubenstein et al concluded in a review that lower-extremity weakness was a significant risk factor and increased the odds of falling about six-fold. Studies have reported that the prevalence of detectable lower-extremity weakness ranges from 48% among community-living older persons, to 57% among residents of

![Figure 3 Observed falls in different training groups (mean value and standard error of the mean are shown).](image-url3)

![Figure 4 15D quality of life scores before, immediately after cessation of training, and 6 months from the baseline measurements (mean and 95% confidence intervals are shown).](image-url4)
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an intermediate care facility, to more than 80% of residents of a skilled nursing facility. We therefore focused part of the training on enhancing the strength of the lower extremities, and in the second group, we also looked to improve gait and balance. Participants of guided training had to be able to perform muscle force training, starting from levels of low strain and increasing the strain of exercises with time; this was not the case in the balance force training as they used a walking frame, and other balance training merely added to the muscle force training. However, both training regimes focused on the improvement of strength and use of the postural muscles. Theoretically, balance training should be more effective in changing the postural control strategy, but this was not the case based on our posturography analysis.

Multifactorial interventions have been successful in some, but not all, fall prevention trials. Several studies favor using physiotherapy as a tool to prevent falls in older adults residing in an institutional setting. Common to all these studies was that they used balance training and walking exercises. In contrast, several other studies were unable to show that rehabilitation prevented falls in these subjects. The studies also used walking and endurance training, as used in the present study. While in some training programs balance improved, in others with similar training programs, no changes were seen. Rapp et al suggested that fallers represent cases with multiple different pathologies and that elderly people with certain symptom complexes respond better to rehabilitation than others. The training periods in

![Figure 5 Usual activities (left) and vitality (right) based on 15D scores in the beginning, immediately after cessation of the training, and after 6 months from baseline measurements (mean and 95% confidence intervals are shown).](image)

![Figure 6 Depression score (left) and mental function score (right) derived from 15D QoL (quality of life) at the beginning, immediately after cessation of the training, and 6 months after commencing the training (mean and 95% confidence levels are shown).](image)
previous studies were 1–3 times per week and did not explain the differences between the efficacies of fall prevention. Perhaps a better effect could be achieved by having shorter but more frequent interventions, which lasted throughout the year. This, however, demands resources drawn from the personnel of elderly homes to transport the patients to training units, and increases the number of rehabilitation personnel needed to perform the training. A further study should be attempted to optimize the weekly training periods.

When inspecting the efficacy of the training program to prevent falls, guided training was more efficient than self-training. The participants were quite passive, with only about half the subjects who were able to participate actually attending the study program. This may be a reflection of the development of a negative attitude when moving from one’s own apartment to the institutionalized setting. A change in such attitudes is needed; however, such a change appears difficult as it would require more in the way of personnel resources than the 0.5 nurses per bed currently regulated by law in Finland today.

Effect on QoL
General HRQoL measures can be used to compare the impact of different diseases and to evaluate the costs of illness.19 Kato et al.33 suggested that taking account of mental confidence is important for physical QoL and that fall prevention self-efficacy (including not only the physical activity per se, but also mental confidence) should be given prominence in the physical QoL of the elderly. We demonstrated using the 15D instrument that psychological and physical components (mood, vitality, mental function, and regular day-to-day tasks) were altered after rehabilitation. Nevertheless, guided training produced significantly less falls. The risk of fall is also important in causing neuropsychiatric symptoms.34 Unlike the present study, most intervention studies have been carried out among community-dwelling elderly, differing in age and physical and mental conditions. It seems that for the elderly there is a tradeoff between training exercises and QoL when it comes to rehabilitation. Supporting the importance of postural stability and QoL when it comes to rehabilitation. Supporting the importance of postural stability and QoL when it comes to rehabilitation. Supporting the importance of postural stability and QoL when it comes to rehabilitation. Supporting the importance of postural stability and QoL when it comes to rehabilitation. Supporting the importance of postural stability and QoL when it comes to rehabilitation. Supporting the importance of postural stability and QoL when it comes to rehabilitation.

Training of previously passive elderly alters their daily routines and may be perceived as being excessive; this was seen as a reason for the reduction of psychological and physical dimensions in the present study. Although the elderly had a positive attitude towards rehabilitation, they experienced a level of fatigue that they could not recover from in time for the next training session. A less forceful regime of training amongst nursing home residents increased the QoL by improving their emotional functioning, vitality, and mental health;35 however, fall outcomes were not documented. A softer start-up level of training and the inclusion of emotional support and attitude education could be used to avoid reductions in QoL by minimizing the effects of “post training fatigue”.

Conclusion
In the present study we compared guided exercises and self-administered training and their role in fall prevention in the elderly. Guided exercises carried out twice a week focused on increasing muscle strength and balance. Elderly with moderate or severe dementia could undertake exercises as part of five person groups, under the supervision of a physiotherapist, and with personal nurses overseeing the self-training participants. After 3 months of training, participants in all groups improved their postural stability. Using posturography, we observed that training induced previously used control strategies for posture; elderly residents started to oscillate around a predetermined attractor and in this vein rejuvenated their postural control. Guided training tended to reduce the number of falls when compared to self-administered training. However, we observed that the QoL of residents was reduced after the training had ended, in terms of mood, mental functions, vitality, and usual activities. This indicated that the training program was perhaps perceived to be too laborious. A further study should be carried out to reveal the differences between guided and self-training efforts with a less strenuous training program, so as to avoid consequences adverse to QoL. We conclude that in residential homes, efforts should be made to increase guided muscle force training, but that training activities should be moderate. Additionally, self-training could be used as a daily supplement to a guided training program.

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Disclosure
The authors report no conflicts of interest in this work.

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Risk factors of falls in community dwelling active elderly

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ABSTRACT

Objective: To search for measures to describe and relate to accidental falls in community dwelling elderly.

Method: A EuroQol EQ-5D questionnaire based on a patient’s otoneurological case history provided a general health related quality of life measure, a fall history for the last 3 months and force platform measures for 96 active elderly from a pensioner organization.

Results: On average, the elderly experienced 0.3 falls over the preceding three months. A fall was seen to cause a significant deterioration in the quality of life and vertigo and caused fear of falling. The postural instability correlated with falls. Vertigo was present among 42% and was most commonly characterized as episodic and rotatory in factorial analysis items relating to vertigo correlated to falls and balance complaints. Four factors were identified and three of these correlated with falls. Vestibular failure correlated to a fall occurring when a person was rising up; Movement intolerance correlated with falls due to slips and trips, and Near-syncope factor correlated to falls for other reasons. In posturography, the variable measuring critical time describing the memory based “closed loop” control of postural stability carried a risk for accidental fall with an odds ratio of 6. The variable measuring zero crossing velocity showed a high rate of velocity change around the neutral position of stance.

Conclusion: Vertigo and poor postural stability were the major reasons for falls in the active elderly. In ageing, postural control is shifted towards open loop control (visual, proprioception, exteroception and vestibular) instead of closed loop control and is a factor that contributes to a fall.

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1. Introduction

People aged 65 years and older represent the fastest-growing population segment of the European Union. Vertigo and dizziness in the elderly have been reported among 30% of elderly of 65 years of age [1] and increases to 60% at 85 years of age [2]. Dizziness and vertigo has been regarded as a significant [2] predictor for falls [3–6]. Rubenstein et al. [7] reported balance disorders and dizziness as the second and third leading causes of falls in older persons, respectively. In a meta-analysis for the risk factors of falls in the elderly, Deandra et al. [8] included data from 28 prospective reports and showed that gait problems, walking aids use and vertigo were the leading predictive causes of falls. Vertigo, unsteadiness, and related symptoms also have an indirect effect on health and often cause a fear of falling [9–11]. Furthermore, dizziness and vertigo in the elderly lead to a reduction of quality of life, and a reduction of mental and physical health [12].

Kerber et al. [13] found an association of poor balance and accidental falls with the outcomes of posturographic measurements. They regarded postural imbalance as a key factor for explaining accidental falls. Among institutionalized elderly, Tuunainen et al. [14] reported that the elderly had a very limited confidence area which was used to support balance. As this area was small (about 5 cm²), it is highly likely that numerous situations arise during daily activities, in which balance will fall outside of this confidence area, and so forcing the elderly to seek external support to prevent a fall. In functional balance tests such as the Tinetti Performance Oriented Mobility Assessment (POMA) [15] and Timed-Up-To-go [16], a risk of falls can be determined on group bases but the tests are sometimes too difficult for impaired elderly adults to undertake. By summing up the Z-scores from different tests Panzer et al. [17] evaluated the risk of fall and the predictive value of the set. The risk for an individual faller was moderately vague based on POMA criteria and dynamic posturography of 31–51%, respectively, but with specificity of 94–100%, respectively [17]. When the full clinical test set was evaluated, the sensitivity increased to 80% but the specificity reduced to 74%. Posturography has been used in the prediction of falls among the elderly [8,18,19]. However, the use of force platforms with or
without postural perturbation has not improved the accuracy of any prediction of a fall [8,18,19]. As such, a more sophisticated analysis of posturography signals might help to understand the mechanisms leading to and predicting falls. Assessment of vertigo and balance in elderly is challenging. The association between falls and vestibular symptoms are quite complex [20]. In contrast to younger adults, elderly adults describe their symptoms in various, non-uniform ways [2]. This uncertainty in describing complaints increases with ageing and is especially complex in institutionalized elderly [14]. Some patients report true vertigo, others describe their dizziness as a sensation of unsteadiness, imbalance, disequilibrium and a feeling of unreality. Complaints such as drop attacks and near-syncope are also commonly reported [14,21]. It is probable therefore, that primary care clinicians and geriatricians commonly undiagnose or misdiagnose dizziness and vertigo in the elderly [22]. In a study conducted by Lawson et al. [12] in 59 patients with vertigo of vestibular origin; 31 (59%) were referred to a Fall and Syncope Unit instead of otolaryngology. In a chart audit, Kwong and Pimlott [23] showed that 46% of elderly who came for primary consultation for vertigo, were either diagnosed improperly or were considered to be simply symptomatic of their natural ageing process. These symptoms are often considered by practitioners to be part of a “geriatric syndrome” because of their multi-symptomatic appearance.

The aim of the present work was to evaluate vertigo and postural stability and the association of these factors in falls among home dwelling active elderly. We especially looked to explore the association of postural stability with vertigo, balance problems and falls.

2. Materials and methods

2.1. Study groups

The study was carried out among members of a local Pensioner Association in the city of Tampere, who encouraged members to volunteer to participate in the study. The City of Tampere institutional review board approved the study protocol. During the study, 96 active home dwelling elderly persons were studied, with a mean age of 70.2 years (range 60–85 years). Their gender, alcohol consumption, medications, disease profile and training profile are shown in Table 1.

2.2. Data collection

In order to establish a case history of vertigo, balance problems and general health, a standardized questionnaire was used in the interview. The questionnaire consisted of 98 questions about the residents’ symptoms, medical history medication and weekly exercise [24–26]. The focus was to describe complaints associated with vertigo, dizziness, and balance and gait.

A general health-related quality of life measure (EQ-5D) was completed [27]. EQ-5D is a widely used method to assess a general-health related quality of life. Due to its simplicity it is more likely to be used in group comparisons than in the evaluation of quality of life in individual subjects. The instrument consists of two parts: one is a thermometer (visual-analogue scale, VAS) and the other comprises five questions related to the patient’s functional capacity (time trade off (TTO) instrument). In the VAS component, the patient is asked to indicate a self-rating of their current health state. The TTO instrument consists of weighted replies to questions of mobility, self-care, usual activities, pain/discomfort and anxiety/depression, which each have three response levels. The TTO score is a product of responses to the five questions, weighted with factors derived from a sample of the general United Kingdom population to provide a ‘social tariff’ TTO utility score [28]. The TTO utility score constitutes a direct indicator of the patients’ own implicit preferences.

2.3. Definition of fall

In this work, a fall may be defined as unintentionally coming to rest on the ground or a lower level, with or without loss of consciousness. Records were made of falls to clarify the cause of falls that occurred during the preceding three months. The data was used to classify the nature of events leading to fall, e.g. as: base of support related (trips and slips), centre of mass related (head movement, body movements), and no obvious reason.

2.4. Force platform posturography

We used a custom-made force platform measuring vertical force distribution over the platform surface [29]. From this force distribution, the postural stability range, elliptic area, force moments and sway velocity were able to be analyzed [30]. During the test, the subject stood without shoes, knees locked, and arms crossed over the chest on the solid platform surface. The duration of the test was 20 s and was performed firstly with the eyes open and then with eyes closed. We chose to use relatively short signals from stabilograms as the stabilogram is not a continuous signal but consists of time dependent variations. In a recent study Haeggstrom et al. [31] studied the effect of sleep deprivation on postural stability. The authors reported that the sleep deprivation estimation accuracy based on the time-interval for open-loop control of stance remained at 6% when the measurement time was shortened to 20 s. Thus, even short signals are satisfactory to reveal the basic sway frequencies and amplitudes that describe the basic uncertainty of postural stability. In this utilizes the data recorded in non-visual conditions. As a result of a hard drive fault however, posturography data could only be analyzed from 67 study subjects.

2.5. Variables

The location of the centre point of force (CPF) can be extracted directly from a preprocessed stabilogram. In preprocessing we

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<table>
<thead>
<tr>
<th>Table 1 Study group characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Alcohol consumption</td>
</tr>
<tr>
<td>No alcohol</td>
</tr>
<tr>
<td>Less than 4 doses (4cl) per week</td>
</tr>
<tr>
<td>5–9 doses per week</td>
</tr>
<tr>
<td>10–20 doses per week</td>
</tr>
<tr>
<td>Medication</td>
</tr>
<tr>
<td>Antihypertensives</td>
</tr>
<tr>
<td>NSAID</td>
</tr>
<tr>
<td>Antidepressants</td>
</tr>
<tr>
<td>Diseases</td>
</tr>
<tr>
<td>MCC</td>
</tr>
<tr>
<td>Hypertension</td>
</tr>
<tr>
<td>Kidney hypofunction</td>
</tr>
<tr>
<td>DM1&amp;2</td>
</tr>
<tr>
<td>Hypo/hyperthyrois</td>
</tr>
<tr>
<td>Training</td>
</tr>
<tr>
<td>No exercise</td>
</tr>
<tr>
<td>Exercise once in a week</td>
</tr>
<tr>
<td>Exercise twice in a week</td>
</tr>
<tr>
<td>Exercise three times in a week</td>
</tr>
<tr>
<td>Exercise more than three times in a week</td>
</tr>
</tbody>
</table>
used a finite impulse response low pass filter which suppressed frequencies above 17 Hz. In addition, the mean values of all signal components were subtracted in order to centre the signals. With positional information we calculated the mean velocity of CPF. We used six additional time domain variables derived from posturography signals based on previous work on the elderly [32] that had the greatest association between age and gender. Our selected variables and their abbreviations were as follows: 95% confidence amplitude in the anterior–posterior direction, \( C(Y); \) the mean of the absolute moment around the medio-lateral axis, \( M(MY) \); the zero-crossing rate of a stationary point in the anterior–posterior direction, \( ZCR(Y); \) the zero-crossing rate of velocity in the medio-lateral direction, \( ZCR(VX); \) the critical time, where an open-loop control changed into an closed-loop control, \( CRI(T); \) the number of samples that belonged to steady-phase standing, \( ST(N). \) For modelling purposes, we took the natural logarithms of the variables to make their distributions closer to normal. Steady phases during quiet standing are illustrated in form [1]. Steady-phase standing was calculated on the basis of the sum of the moving variances of leaning moments about the medio-lateral and anterior-posterior axes. A summed moving-variance signal was divided by the square of the subject’s mass to suppress its contribution. A moment-signal sample \( (M_i) \) was considered to belong to a steady phase if the local variation of five successive moment samples divided by the square of subject’s mass \( (m) \), was less than 0.04. The calculation of the local variance about a single axis in point \( M \) is presented in Formula (1).

\[
T(M_i) = \frac{1}{4m^2} \sum_{j=1}^{j=+2} (M_j - \bar{M})^2
\]

The zero-crossing rate of velocity was calculated by counting the numbers of samples of the in stabiligogram signal crossing the mean zero line during 15 s of measurement. The critical time for controlling the open loop versus the closed loop of posture [33,34] was calculated in a 15 s signal where we calculated the critical time \( CRI(T) \) by fitting lines for short and long time control. We used sample intervals that could have values from 1 to 748. These resemble the time differences from 0.02 to 14.98 s. The value of 1 provides the squared distance between the COP points \( (x_1, y_1) \) and \( (x_2, y_2) \). For the sample long time window we sum up all possible squared differences between points \( (x_i, y_i) (x_i+1, y_i+1) \) where \( i \) is allocated from a value to 1 from 748. This calculation gives us a point \( (\Delta x_i, \Delta y_i) \). Increasing the time window, we get the points \( (\Delta x_i, \Delta y_i) \). With these points, we fit two lines for small and large \( i \) values. Small \( i \) values represents the short time control where a person can sway relatively freely. Large \( i \) values however take into account that a person should become aware of the swaying phase. The intersection \( \Delta \) gives the time or sample number that indicates when the nature of the control system changes.

The analysis of the time-interval for open-loop control of the stance has been used previously for example to predict the sleep deprivation time of individual subjects [31] and for improving the clinical utility of posturography as a fall-risk screening tool [35]. These authors also used so called fractal dimension of sway path. This measures the self-similarity of sway within the range of different time scales. A somewhat easier way to describe the same phenomenon is the use of critical time [33]. These measures provides the time when the characteristics of postural control is changing. In an open loop control if a subject moves slightly and within a short time window there is no need to interfere with an active muscle control. However, when the time after previous correction movement has become sufficiently long there will be the need for a new active postural controlling event. In this case the nature of controlling has changed from open loop control in to closed loop control. This time is called critical time.

### 2.6. Statistical analysis

The risk of falls was analyzed using a logistic regression analysis. Differences in the continuous variables between training groups were analyzed with the Student’s \( t \)-test, and in discrete variables by using a Mann–Whitney \( U \)-test or Wilcoxon Signed Rank test. The associations in continuous variables were examined with a Pearson’s test, and in discrete variables using Kendall’s tau. Factor analysis with varimax rotation was used to search for factors associated with vertigo and balance problems.

### 3. Results

#### 3.1. History of falls

Falls were recorded in 30 of the 96 elderly. The conditions under which the falls occurred is shown in Table 2. One subject had post-fall amnesia and became unconscious for a short time (eye witnessed). It led to visit of a doctor, as was also the case in one other subject. In the remaining cases, the fall did not lead to any adverse health consequences. In 10 cases, the fall(s) were eye witnessed. Falls were commonly related to slips or stumbles (Table 2). Fallers were seen to have significantly greater FES-I scores \((t = 3.8, p < 0.001)\) than non-fallers.

The falls were associated with reduced quality of life. When analyzing different constituents of the TTO instrument, pain \((t = 3.02, p = 0.003)\) and mood (depression) \((t = 2.10, p = 0.039)\) differed with statistical significance between fallers and non-fallers. No differences in mobility, usual activities or self-care were observed.

#### 3.2. Modeling vertigo in the elderly

Attacks of vertigo, floating sensation, postural instability were common among the elderly (Fig. 1). Vertigo was most commonly characterized as episodic and rotatory (42%) (Fig. 2). Only 12% of the cohort experienced balance problems. Hearing loss and tinnitus were statistically as common as vertigo (Table 3). Vertigo was associated with nausea and vomiting \((r = 0.655, p < 0.001)\), rotatory type \((r = 0.855, p < 0.001)\), and frequent episodes \((r = 0.747, p < 0.001)\) and long lasting attacks \((r = 0.720, p < 0.001)\). It also correlated with the incidence of sudden slips and falls \((r = 0.703, p < 0.001)\). Falls correlated with complaints of vertigo \((r = 0.311, p = 0.002)\), postural instability \((r = 0.231, p = 0.024)\), nausea and vomiting \((r = 0.238, p = 0.019)\) and positional change \((r = 0.312, p = 0.002)\). In

### Table 2

Falling conditions and consequences.

<table>
<thead>
<tr>
<th>Condition</th>
<th>n = 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falls</td>
<td></td>
</tr>
<tr>
<td>Cause of falls</td>
<td></td>
</tr>
<tr>
<td>Slipping (slippery surface)</td>
<td>12</td>
</tr>
<tr>
<td>Tripping (obstacle)</td>
<td>9</td>
</tr>
<tr>
<td>Fall when standing up</td>
<td>6</td>
</tr>
<tr>
<td>Falling from bed</td>
<td>3</td>
</tr>
<tr>
<td>Falling environment</td>
<td>17</td>
</tr>
<tr>
<td>Outdoors</td>
<td></td>
</tr>
<tr>
<td>Indoors (in appartment)</td>
<td>13</td>
</tr>
<tr>
<td>Eye writness</td>
<td>10</td>
</tr>
<tr>
<td>Consequences</td>
<td></td>
</tr>
<tr>
<td>Unconsciousness</td>
<td>1</td>
</tr>
<tr>
<td>Other health consequence</td>
<td>1</td>
</tr>
<tr>
<td>Doctors consultation</td>
<td>5</td>
</tr>
</tbody>
</table>
logistic regression analysis, only near-syncope and drop attacks explained the falls (odds ratio 2.52).

In principal component analysis, four major components were identified that described 72% of the data regarding symptoms of “presbyequilibrium” among the elderly (Table 4).

Four factors were identified in the analysis:

1. **Vestibular failure (Factor 1)** is characterized by vestibular fault. The elderly had symptoms of true vertigo (rotatory) and sensation of movement (floating) that was periodic and provoked by physical strain or activity. Nausea often accompanied the attack and elderly subjects often experienced falls when rising up from a chair or changing their body position.

2. **Movement intolerance (Factor 2)** was characterized by mobility and gait problems. There was an association with chronic instability. These subjects had problems with their base of support and experienced falls during sudden slip or trip episodes.

3. **Frail presbyequilibrium (Factor 3)** was characterized by postural instability, poor muscle strength and the need for assistance in movements. The elderly preferred to use their hands to assist themselves when rising from a chair and used supporting devices for walking. This factor correlated with a fear of falling measured with FES-I.

4. **Near-syncope (Factor 4)** was characterized by a tendency to fall and episodes of near-syncope with short intensive attacks of vertigo requiring bed rest. The subjects also complained of a fall due to other reasons often not recorded by themselves.

When analyzing the association of the factors with falls with logistic regression analysis, factors 1, 2 and 4 were significantly associated with falls (p = 0.002). Thus vertigo, movement intolerance and near-syncope were significant risk factors for falls with odds factors ranging from 1.5 to 1.8. In logistic regression analysis, the model explained about 22% of the falls.

### Table 3
Vertigo, balance problems, hearing loss and tinnitus among 96 elderly persons.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Present</th>
<th>Not present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertigo</td>
<td>42</td>
<td>54</td>
</tr>
<tr>
<td>Balance problems</td>
<td>11</td>
<td>85</td>
</tr>
<tr>
<td>Hearing loss</td>
<td>36</td>
<td>60</td>
</tr>
<tr>
<td>Tinnitus</td>
<td>35</td>
<td>61</td>
</tr>
</tbody>
</table>

### Table 4
Association of factors in principal component analysis. Below is shown the odds ratio for falls, as derived from logistic regression analysis. The reasons for falls and FES-I scores were tested with Mann–Whitney U-test and ANOVA, respectively.

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation of the surrounding</td>
<td>0.669</td>
<td></td>
<td>0.666</td>
<td></td>
</tr>
<tr>
<td>Floating sensation</td>
<td>0.692</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tendency to fall</td>
<td></td>
<td>0.721</td>
<td></td>
<td>0.761</td>
</tr>
<tr>
<td>Postural instability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near-syncope and drop attacks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotatory character of vertigo</td>
<td>0.901</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of attacks</td>
<td>0.79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of attacks</td>
<td>0.752</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity of attacks</td>
<td>0.674</td>
<td></td>
<td>0.623</td>
<td></td>
</tr>
<tr>
<td>Nausea</td>
<td>0.766</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudden slips or trips</td>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position provoking</td>
<td>0.827</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure provoking</td>
<td>0.734</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical activity provoking</td>
<td>0.764</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance problems</td>
<td></td>
<td></td>
<td></td>
<td>0.772</td>
</tr>
<tr>
<td>Mobility problem</td>
<td>0.827</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arise from chair</td>
<td></td>
<td></td>
<td></td>
<td>0.643</td>
</tr>
<tr>
<td>Association and correlations with respective factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odds ratio for fall (logistic regression analysis)</td>
<td>1.8 (1.3–2.3)</td>
<td>1.8 (1.3–2.3)</td>
<td>Ns</td>
<td>1.5(1.0–2.0)</td>
</tr>
<tr>
<td>Reason for a fall (Mann–Whitney U-test)</td>
<td>Rising up (p = 0.01)</td>
<td>Slips, trills (p = 0.03)</td>
<td>Ns</td>
<td>Other reason (p = 0.001)</td>
</tr>
<tr>
<td>FES-I scores (ANOVA)</td>
<td>Ns</td>
<td>Ns</td>
<td>P = 0.01</td>
<td>Ns</td>
</tr>
</tbody>
</table>
predicting falls. The variable measuring zero crossing velocity showed a high rate of velocity change around the neutral position of stance. The other interesting variable was the critical time for controlling the open loop versus the closed loop of posture [33,36]. This variable differed significantly between fallers and non-fallers \((t = 2.32, p < 0.02)\) whereas the variable measuring zero crossing velocity was of borderline significance \((t = 2.00, p = 0.05)\). In logistic regression analysis, falls correlated with these two variables \((p < 0.001)\). The critical time for control of the open loop versus closed loop control of posture had an odds ratio for falls of 6.3 (4.9–8.7) and a crossing of neutral line value of 1.2 (1.1–1.3) (Fig. 3). Noteworthy is that the elderly with a risk of falling tended to oscillate from the neutral position without memory of the last position. The model based on posturographic analysis explained about 23% of the variability of the falls.

In correlation analysis, several of the variables describing vertigo were associated with the ability to hold a stable stance. When evaluating the factors derived from factorial analysis, factors 2 and 4 correlated highly significantly with the critical time for control in open versus closed loop postural control \((p < 0.01)\). Factor 1 had only a tendency to correlate with the ability to hold neutral position \((p = 0.08)\).

Next we evaluated what factors influence the performance of critical time for control in open and closed loop control. In the model, vertigo attack severity \((t = 4.44, p < 0.001)\) and the character of vertigo \((t = 2.79, p = 0.007)\) were statistically significant. The model explained 25.6% \((p < 0.001)\) of the variability, indicating that critical time for control in open vs. closed loop control is partly explained by vestibular system dysfunction.

We evaluated the role of physical exercise on postural stability measured with posturography. Even a moderate level of exercise improved postural stability and especially, that the parameter measuring the critical time for control in open versus closed loop of posture improved significantly \((p < 0.001)\). In logistic regression analysis those not exercising had significant risk for fall with odds ratio of 10.0 (range 7.7–13.0). However only 5 subjects did not exercise at all.

4. Discussion

The elderly in the present cohort were relatively young, socially active, and participated in the study voluntarily as promoted by the local pensioner organization. They demonstrated an association of vertigo with postural stability and falls. In the stabilogram, two measures (the zero crossing velocity and the critical time ratio for open versus closed loop control of balance) were associated with the falls. Furthermore, the characteristics of vertigo could be related to falls occurring in specific events. The complaint history was quite well defined when compared with very old elderly or residential home dwellers in whom multiple confounding factors often distort the proper vestibular symptom history [37,38]. Among the active elderly, the associations of vestibular and balance disorders with falls were easier to identify. Based on complaint history, four major factors were identified. In factorial analysis vestibular failure was associated with chair arise (changes in head position). Movement sensitivity was associated with slips and trips and near-syncope was associated with falls of variable and often unexplained reasons. An understanding of factors associated with falls and with posturography measurement would render it possible to identify and rehabilitate the elderly to diminish the risk of accidental falls. The symptoms were taken from the patients and not based on neuro-otological testing. Therefore the aetiology of vertigo and balance disorders cannot be described yet. In institutionalized elderly we recently evaluated the etiological aspects of vertigo and about 50% had positional vertigo [39]. However the younger elderly population differs in duration of vertigo attacks and may reveal different aetiology as the institutionalized elderly and in many cases mimic of that of Meniere’s disease [40]. A further study should be performed to reveal the aetiology of vertigo and balance disturbances.

4.1. Ageing and postural stability

Deandrea et al. [8] showed that gait and balance impairments are the most serious risk factors for falls in the community dwelling elderly, seconded only by a history of previous falls. Gait and balance impairments were deemed to carry, respectively around a two and three fold increased risk for falling [3–6], as was also found in the present study. A deteriorated body sway may stem from an error or the deterioration of the common neural substrates that serve balance and gait [19] and also from an error in corrective movements after a perturbation of posture. In line with other researchers, we observed that in trying to predict a faller, conventional posturography measures based on the area and velocity determination of body sway were not useful. The
calculated variables retrieved from the stabilogram demonstrate quite a high odds ratio for falls.

The testing of a person blindfolded excludes the visual feedback used in the open loop control of posture [33,36]. When investigating the different sensory feed-back systems for posture, Hytönen et al. [41] showed that visual influx has a crucial role in the postural control of the elderly whereas the proprioception and plantar skin pressoreceptors influx are strongly reduced, undermining their role in controlling the body sway. This reduction of proprioception and exteroception also affects the detection of torque in the ankle joint which explains why the zero crossing velocity was increased. According to Maki et al. [19], reduced proprioception causes “reduced stiffness” or reduced postural “reflex gain”, leading to increased instability of postural control. If the vestibular system gain is erroneous (as can be expected in the elderly with vertigo) the open loop control of posture becomes more important. Hirvon et al. [42] demonstrated in a head autorotation test amongst elderly people living in residential home, that especially at higher frequencies, the gain of vestibuloocular reflexes was reduced although the time constant increased. This results in over-dimensional anticipatory reflexes at lower frequencies and makes postural control unreliable. Inadequate vestibular reflexes ultimately lead to an erroneous efferent copy in the closed loop control signal and explains why the elderly frequently use open loop control in their postural control. Open-loop control means that the postural control strategy is planned beforehand and does not depend on feedback from the surrounding environment. Closed-loop control on the other hand means that the postural control is dependent on feedback from the internal environment, which stems from vestibular, visual and somatosensory inputs. The difference between usage of the open and closed loop control mechanisms is described as the critical time in the present work [33,36]. We found this variable important as it revealed the risk of falls and also correlated with the fear of falling. A prolongation of the critical time indicates that the elderly neglect the need of updating the postural position and loose their concept of position for a short time.

4.2. Vertigo, dizziness and postural stability

Belal and Glorig [43] studied dizzy patients over the age of 65 and found specific causes of vertigo and dizziness in 21% of the elderly. In the remaining 79%, no specific diagnosis could be established, for which the authors coined the term “primary disequilibrium of ageing”. Tuunainen et al. [14] introduced the term “presbyequilibrium” to describe the complex pattern of vertigo, dizziness, balance problems and a fear of falls in the elderly. The single most common dizziness or balance complaint in the Gothenburg cohort was that of poor balance/general unsteadiness, being present in almost 60% of the subjects [2]. The elderly understood and described their dizziness in many ways [2]: They commonly use various nonspecific terms to describe their complaints of balance disorders, such as vertigo, general unsteadiness, dizziness, lightheadedness, fainting or other illusory sensations as indications of the medically specific symptoms of true vertigo. In addition, they often complain of a fear of falling, gait disorders, postural mis-match, oscillopsia, and syncope or near syncope that may also be an expression of dizziness. Some elderly report true vertigo, a hallucination of motion that is most commonly a distinct sensation of rotation or rocking. Often they tend to underreport their symptoms [37]. We found that episodic vertigo was present in 42% of our study group whereas postural instability was experienced by only 10%. We used exactly the same questionnaire in this study, as was used in the case of institutionalized elderly, in whom the vertigo and balance problems were opposite [20].

Although the majority of the elderly in this study regarded themselves to be active by doing physical exercises, their lifestyle may be stigmatized by the decreased physical activity caused by retiring from active working life [44]. Another important consideration is that vertigo leads to reduced self-exercise and so reduces physical fitness and may lead to muscle weakness in the hip muscles. Rubenstein et al. [7] concluded in a review, that lower-extremity weakness was a significant risk factor and increased the odds of falling by about six-fold. Studies have reported that the prevalence of detectable lower-extremity weakness ranges from 48% amongst community-living older persons [45], to 57% amongst residents of an intermediate-care facility [15], rising to more than 80% in residents of a skilled nursing facility [46]. We could not demonstrate any dose-response effect of physical exercise in either falls or postural stability, indicating that physical exercise may not be a critical factor for the incidence of falls among the active elderly.

Michael et al. [47] evaluated in a literature survey, the factors associated with falls. The multifactorial falls risk assessments identified by various groups were fairly consistent across a range of risk factors, including the circumstances of previous falls, medical comorbidities, neurological assessment, lower extremity joints problems and weakness, medication use, orthostatic hypotension, visual impairment, gait, balance and mobility concerns, impaired functional activities, environmental hazards, cognitive impairment, fear of falling, and urinary incontinence. Noteworthy was that in this analysis, the only vestibular aspects identified were related to balance problems and none of the research work focused on vestibular function or vertigo. Thus, vestibular disorder among elderly fallers is in many cases either non-diagnosed or neglected. The estimated direct medical costs for fatal and non-fatal fall-related injuries for community-dwelling people aged 65 or older was $19.2 billion in 2000 (AGS Guideline for the prevention of falls in older persons, 2001) [48], with one study estimating that this cost could reach $43.8 billion by 2020 [49]. Therefore, a trained vestibular nurse may be an important adjunct for observing vestibular deficit and to classify those persons for an interactive rehabilitation programme [14].

5. Conclusions

We have demonstrated an association between falls, vestibular complaints and the postural stability of force posturography. In factorial analysis based on complaints, four major factors were retrieved that correlated with reasons to fall. In posturography, the open loop and closed loop control mechanisms were described as the critical time and were a predictor of fall. The elderly of the study could define their balance and vestibular complaints in contrast to the institutionalized elderly who often underreport symptoms of dizziness and often do not consciously recognize dizziness or balance problems as an abnormality that should be investigated. For these reasons, it is important for practitioners to maintain a high awareness of balance disorders in the elderly and to specifically inquire about these symptoms and to examine for signs of these often treatable conditions. We would suggest that services for dizzy patients should allow for the efficient and seamless movement between “falls” clinics run by geriatricians and a balance/vertigo service run by otolaryngology physicians and surgeons. We further recommend that they should collaborate and have joint working schedules to optimize the management and the sometimes difficult assessment of presbyequilibrium. This practice should be in place when the elderly are still in the active phase of their life.

Conflict of interest

None.
References