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HEARING IMPAIRMENT AND TINNITUS IN THE ELDERLY

by

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Ku vaa loppuis toi kauhia humina pääst.

En sunka mää vaan saanu sin vikka?

-Väinö Linna

ABSTRACT

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HEARING IMPAIRMENT AND TINNITUS IN THE ELDERLY
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The purpose of this study was to gather information on hearing impairment and related factors among elderly people. The HHIE-S questionnaire (Hearing Handicap Inventory for Elderly-Screening) and a single hearing question (”Do you feel you have a hearing loss”) were compared to audiometric hearing thresholds (N=164). HHIE-S was reliable for detecting moderate or worse hearing impairment. The single question was equally sensitive and more specific in identifying mild hearing impairment. The prevalence of hearing impairment was evaluated in four age cohorts (70, 75, 80 and 85 years, N=4067) in Turku, Finland. The HHIE-S cut-off score >8 as an indicator of at least mild hearing impairment yielded prevalence values of 37.7% - 54.1%, and a score >18 (moderate or more severe hearing impairment) was 21.1% - 38.9%. The single question test was positive in 25.5% - 46.2%.

Hearing aid compliance and problems experienced by hearing aid users were recorded as informed by the participants in a mailed interview (N=249/4067). The hearing aids were used daily by 55.4%, and never by 10.7%. Use sank with advancing age.

The disturbance caused by tinnitus among 583 subjects was compared to their level of alexithymia (TAS-20) and depressiveness (BDI). Depressiveness was weakly associated with annoying tinnitus, but not alexithymia.

The prevalence of hearing impairment can be measured by enquiry. Hearing aid compliance should be improved by technical means and better counseling. The factors affecting the distress experienced by tinnitus patients need further study.

Keywords: Hearing, elderly, prevalence, hearing aid, compliance, tinnitus, depression, alexithymia.

TIIVISTELMÄ

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Ikähuonokuuloisuus on hyvin yleistä ja suuri osa kuulonkuntoutuksen voimavaroista suunnataan eläkeikäisten kuntoutukseen. Tämän tutkimuksen alkaessa olivat voimavarat niukat ja kuulokojejono pitkä Varsinais-Suomessa. Tutkimuksen tarkoituksena oli selvittää kyselytutkimusten käytettävyyttä huonokuuloisuuden yleisyyttä arvioitaessa, kuulovian yleisyyttä ja kuulokojeiden käyttöä eläkeikäisillä. Halusimme myös analysoida kuulovikaan läheisesti liittyvään korvien soimiseen eli tinnitukseen vaikuttavia tekijöitä.

Vertasimme HHIE-S-kyselyä (Hearing Handicap Inventory for Elderly-Screening version) ja kysymystä ”Koetteko itsenne huonokuuloiseksi?” mitattuihin kuulokynnyksiin. HHIE-S osoittautui luotettavaksi tunnistamaan vähintään keskivaikean kuulovian, kun taas yksinkertainen kuulokysymys oli yhtä herkkä ja spesifimpi lievän kuulovian tunnistamisessa. Neljän ikäkohortin (70-, 75-, 80- ja 85-vuotiaat, N=4067) huonokuuloisuuden yleisyyttä kysyttiin postikyselyllä. Vähintään lievän kuulovian esiintyvyyttä kuvaava HHIE-S-kyselyn raja-arvo >8 ylittyi 37,7, 42,4, 47,2 ja 54,1 prosentilla näissä ikäluokissa, kun raja-arvon >18 mukaan vähintään keskivaikea kuulovika oli 21,1, 25,6, 28,8 ja 38,9 prosentilla. Kuulokysymykseen vastasi myöntävästi 25,5, 32,7, 38,7 ja 46,2 prosenttia vastaajista.

Kuulokojeiden käyttöä ja siihen liittyviä ongelmia kysyttiin postikyselyllä. Tässä otoksessa (N=249) 55,4% käytti kuulokojettaan päivittäin ja 10,7% ei käyttänyt kojettaan. Yleisimpiä syitä kuulokojeen käyttämättömyyteen olivat taustaäänten häiritsevyys, käsittelyvaikeudet ja vinkuminen.

Korvien soimisen eli tinnituksen aiheuttamaa haittaa ja sen yhteyttä aleksitymiaan (TAS-20, Toronto Alexithymia Scale) ja masennusoireisiin (BDI, Beck Depression Inventory) arvioitiin 583 henkilön otoksessa. Korkeilla BDI-arvoilla oli heikko yhteys häiritsevään korvien soimiseen, mutta TAS-20-arvolla ei yhteyttä todettu.

Vanhuusiän huonokuuloisuus on normaali ilmiö ja sen esiintyvyyttä voidaan mitata kyselytutkimuksella. Kuulokojeiden käyttömyöntyvyyttä tulee parantaa teknisin ja neuvonnallisin keinoin. Tinnituksen häiritsevyyteen vaikuttavat tekijät vaativat lisätutkimusta.

Avainsanat: Kuulo, vanhukset, prevalenssi, kuulokoje, hoitomyöntyvyys, tinnitus, masennus, aleksitymia.

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ABBREVIATIONS AND DEFINITIONS

AUC	Area Under Curve
BDI	Beck Depression Inventory
BEHL	Better Ear Hearing Level
BMHS	Blue Mountains Hearing Study
BTE	Behind The Ear (hearing aid)
CL	Confidence Limit
dB	Decibel
DNA	Deoxyribonucleic Acid
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, fourth edition
EHLS	Epidemiology of Hearing Loss Study
EUWG	European Union Working Group on Genetics of Hearing Impairment
HHIA	Hearing Handicap Inventory for Adults
HHIE	Hearing Handicap Inventory for Elderly
HHIE-S	Hearing Handicap Inventory for Elderly-Screening version
HL	Hearing Level
HPI	Hearing Performance Inventory
ISO	International Organisation for Standardization
ITE	In The Ear (hearing aid)
kHz	Kilohertz
MMSE	Mini–Mental State Examination
OR	Odds Ratio
PTA	Pure Tone Average
RITE	Receiver In The Ear
ROC	Receiver Operating Characteristics
RR	Relative Risk
rTMS	Repetitive Transcranial Magnetic Stimulation
SCID-I/II	Structured Clinical Interview for DSM-IV
SCL-90-R	Symptom Checklist 90 (Revised)
SF-36	36-item Short-Form Health Survey
SOAE	Spontaneous Otoacoustic Emissions

SRT	Speech Reception Threshold
TAS-20	Toronto Alexithymia Scale
TDH-39	Telephonics Dynamic Headphone, model 39
THI	Tinnitus Handicap Inventory
TRT	Tinnitus Retraining Treatment
WEHL	Worse Ear Hearing Level
WHO	World Health Organization

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by Roman numerals I-IV.

I. Salonen J, Johansson R, Karjalainen S, Vahlberg T, Isoaho R. Relationship between self-reported hearing and measured hearing impairment in an elderly population in Finland. Int J Audiol 2011; 50: 297-302.

II. Salonen J, Johansson R, Karjalainen S, Vahlberg T, Jero J-P, Isoaho R. Prevalence of hearing problems in four urban elderly cohorts assessed by two self report methods. (Submitted)

III. Salonen J, Johansson R, Karjalainen S, Vahlberg T, Jero J-P, Isoaho R. Hearing aid compliance among elderly. B-ENT (In press)

IV. Salonen J, Johansson R, Joukamaa M. Alexithymia, depression and tinnitus in elderly people. Gen Hosp Psychiatry 2007; 29: 431-435.

1. INTRODUCTION

Hearing impairment is a major public health and health economic problem. Some 0.1–0.3% of all newborn children have impaired hearing, but over 50% of the population above 75 years has a hearing impairment that requires rehabilitation. The estimated prevalence of some level of hearing impairment in the whole adult population of Finland is 15–18%, which equals about 800,000 people, and 14,000 hearing aids are distributed annually (Sorri et al. 2001). A modern hearing aid will work for approximately 4–5 years. Since the costs for one hearing aid and its fitting are about 900 Euros, the yearly expenditure on hearing aids should amount at least to 13 million Euros, but this figure cannot be verified, since no collected data on hearing aid costs are available in Finland.

Hearing impairment affects practically everyone in the ninth and tenth decade of age (Corna et al. 2009), although rehabilitation is not always needed. A Nordic-British joint project on Hearing Impairment Among Adults (Sorri et al. 2001) identified already in 2001 a need for precise information on the prevalence of hearing impairment. Detailed information on what is needed is a prerequisite for planning of hearing rehabilitation and this study was designed to collect such information. What we did know was that the resources were too limited because elderly patients in southwestern Finland queuing for hearing aid fitting had to wait for their turn for over two years.

There are several survey methods for estimating the occurrence of hearing impairment in the population. The Hearing Handicap Inventory for Elderly – Screening version (HHIE-S) has been validated and is reasonably accurate and sensitive (Weinstein and Ventry 1983, Weinstein et al. 1986). In the Blue Mountain Hearing Study sensitivity and specificity values of 58% and 85% for mild hearing impairment and 80% and 76%, respectively, for moderate hearing impairment measured at a cut-off score >8 were reported (Sindhusake et al. 2001). HHIE-S has been used successfully in some large scale epidemiological studies, but there was no translated or validated version of the survey in Finnish at the time when our project started. Also simple self report methods have been used in epidemiological studies, e.g., a single question ”Do you feel you have a hearing loss?”. Such methods seem to be more specific but less sensitive (Sindhusake et al. 2001). One advantage of this kind of question is that it might measure better the need for hearing rehabilitation. A patient with high score in a questionnaire is unlikely to use a hearing aid if he or she does not feel any disability.

In previous studies compliance with the use of hearing aids among the elderly has been disappointingly low: non-use rates of 24-30% have been reported (Sorri et al. 1984). There is some evidence that compliance has improved with the availability of modern digital hearing aids during the last decade (Vuorialho et al. 2006). Hearing aids improve the person's social, emotional and communicative functions, and - according to some studies (Cacciatore et al. 1999) - even cognitive function and depression. Thus, non-use of hearing aids is a lost opportunity to improve functional capabilities for the elderly, in addition to being a waste of resources. The common reasons for non-use of a hearing aid need to be established to identify persons who will use hearing aids appropriately, to optimize equipment selection and to improve the counseling needed for optimal hearing rehabilitation.

Tinnitus is a sound perception that does not have any origin outside the subject's head. Most often tinnitus is subjective, i.e., only the individual hears the sound. It is not, in fact, exactly a sound but rather a perception of sound, and it originates either from the inner ear or, more often, from the auditory pathways of the central nervous system. Often subjective tinnitus is associated with hearing impairment. Objective tinnitus is a real sound that originates from arteries, veins, joints or muscles, and it is audible or measurable by other observers.

As hearing impairment becomes more prevalent with age, tinnitus is also more common among the elderly and a prevalence of 30% has been reported in an elderly population (Sindhusake et al. 2003). Most subjects with tinnitus are not significantly annoyed by it. There seems to be a clear association between mental health problems (e.g., depression) and the degree of annoyance caused by tinnitus (Belli et al. 2008). The term alexithymia refers to person's inability to recognize and express feelings. Alexithymia is known to be associated with several psychosomatic diseases and although many otolaryngologists consider tinnitus as some kind of psychosomatic disease, there is only little data on the relationship between tinnitus and alexithymia.

The need for this study stems, firstly, from the need of more knowledge on the prevalence and assessment methods of hearing impairment among the elderly. Secondly, there is a need to evaluate the effectiveness of current hearing aid rehabilitation and factors influencing it. The study enabled, thirdly, research on tinnitus and on the psychological factors associated with the annoyance caused by tinnitus among the elderly.

2. REVIEW OF THE LITERATURE

2.1 Hearing impairment among the elderly

There are two generally accepted, international classifications of hearing impairment (Table 1). The World Health Organisation's (WHO) Grades of hearing impairment was originally (1991) defined by the average of pure tone thresholds over three frequencies [0.5, 1 and 2 kilohertz (kHz)] of the better ear ($BEHL_{0.5\text{-}2\ kHz}$). A more recent classifications (2006) includes a fourth frequency, 4 kHz. The European Working Group on Genetics of Hearing Impairment (EUWG)(1996) uses a four frequency average (500, 1000, 2000 and 4000 Hz) of the better ear ($BEHL_{0.5\text{-}4\ kHz}$) for defining hearing impairment. These classifications differ also with respect to the decibel (dB) limits of the degrees of hearing impairment (Table 1). The purpose of the WHO classification was to describe the epidemiological burden of hearing impairment globally. The European Union's classification was developed especially for studying the relations between, on the one hand, hearing impairment and different audiometric patterns and, on the other hand, genetic patterns.

The subjective feeling of hearing impairment has been used in several studies as an indicator of hearing impairment. Although the subjective feeling of hearing impairment does not relate directly to any psychoacoustically measured hearing level, it may be an indicator of the subjective distress caused by hearing problems and of a need for hearing rehabilitation.

Table 1. Grades of hearing impairment according to the World Health Organization's old and new definitions and the European Working Group on Genetics of Hearing Impairment.

	WHO 1991	WHO 2006	EUWG
Grade of hearing impairment	Pure Tone Average 0.5-2 kHz BEHL (dB)	Pure Tone Average 0.5-4 kHz BEHL (dB)	Pure Tone Average 0.5-4 kHz BEHL (dB)
Normal	0-25	0-25	0-19
Mild	26-40	26-40	20-39
Moderate	41-60	41-60	40-69
Severe	61-80	61-80	70-94
Profound	≥81	≥81	≥95

BEHL, Better ear hearing level; WHO, World Health Organization; EUWG, European Working Group on Genetics of Hearing Impairment.

2.1.1 Etiology and pathology

Basically, the same etiology of hearing impairment applies for the oldest age groups as for the younger age groups with the addition of presbycusis, age-related hearing impairment. The prevalence of early childhood hearing impairment is 0.1-0.3%. The most common etiologic factor for hearing impairment in childhood is genetic. Etiologically important are also prematurity, hypoxia, hyperbilirubinemia, prenatal infections (e.g., rubella, cytomegalovirus, toxoplasma), ototoxic medications, and meningitis (Korver et al. 2011).

The elderly of today have been children in the pre-antibiotic era. Access to physicians was very limited in the early 1900's, and both medical and operative treatments were far from adequate by modern standards. In the 1950's acute otitis media led to acute mastoiditis in 0.4% of the cases (Palva and Pukkinen, 1959), but in 1974 - 1981 the risk was 0.004% (Palva et al. 1985). Chronic ear infections and their sequelae are a common finding in elderly.

Otosclerosis affects typically young adults. In otosclerosis, bone remodeling in the otic capsule causes conductive hearing impairment, and if the disease affects inner ear, also sensorineural hearing impairment ensues. Several genomic aberrations linked to otosclerosis have been found, but also environmental and immunologic factors may be involved (Schrauwen and van Camp, 2010). Severe otosclerosis can lead to profound combined hearing impairment; cochlear implants are sometimes needed (Calmels et al. 2007). The prevalence of otosclerosis with conductive hearing impairment is 0.3-1%, but otosclerotic changes in temporal bone specimens occur in 2.5% (Declau et al. 2001). The cochlear type of otosclerosis, presenting as sensorineural hearing impairment, is clinically impossible to distinguish from other types of sensorineural hearing impairment.

Ménière's disease is an inner ear disease that causes fluctuating hearing impairment, tinnitus and vertiginous attacks. The mechanism is probably related to endolymphatic hydrops, as evidenced by pathological specimens and gadolinium enhanced magnetic resonance imaging (Nakashima et al. 2007). Still, the exact pathophysiology of the disease is unknown. The prevalence of Ménière's disease according to hospital record based population studies is 20-50/100,000 (Kotimäki et al. 1999), and according to a mailed questionnaire study (Havia et al. 2005) 513/100,000. In Ménière's disease, hearing at frequencies 500-4000 Hz declines at a mean rate of 1 dB/year (Kotimäki et al. 2001); 11.7% of the patients have bilateral disease.

Noise-induced hearing impairment is caused by excessive acoustic energy that causes irreversible trauma to the hair cells. The reported annual occurrence of occupational noise-induced hearing impairment was 858 cases in 2000 in Finland; in the 1970's the occurrence was about twice as high (Mrena et al. 2007). In addition to occupational noise, the majority of men in the age cohorts born before 1927 attended World War II, and were exposed to noise caused by shooting and explosions. Hearing protectors against occupational noise became gradually more widely used during the 1970's. Recreational sources of noise, music and hunting, cause also hearing impairment (Clark et al. 1991).

Hearing impairment affecting only one ear is mainly due to one of two causes: cochleovestibular schwannoma and acute idiopathic hearing loss. The prevalence of cochleovestibular schwannoma is not clear. A magnetic resonance imaging study by Anderson et al. (2000) reports a prevalence of 7/10,000 but autopsy studies have reported a prevalence of up to 1/100 (Karjalainen et al. 1984). The annual incidence of acute idiopathic hearing loss is about 15/100,000 inhabitants in southwestern Finland (unpublished data by the author), and the life-time risk is approximately 1%. The published data on this subject is scarce and insufficient for generalization.

Age-related hearing impairment (presbycusis) is classically divided into four categories by histological findings (Schuknecht 1964). *Sensory presbycusis* is caused by degeneration of the organ of Corti, and is characterized by steeply sloping, high-frequency hearing impairment. The characteristic changes in the inner ear are similar to noise-induced hearing impairment, and at least a part of it may be caused by life time exposure to noise (Gates & Mills, 2005). *Strial or metabolic presbycusis* is associated with atrophy of the stria vascularis. This condition is related to a loss of the expression of genes involved in ion transporting enzymes and to a reduction in the endocochlear potential. Ganglion cell loss is typical for *neural presbycusis.* Compound action potentials are reduced in some presbycusis patients, but it is currently impossible to distinguish if this is due to neural loss or to decreased endocochlear potential. A decline in the synchronized neural activity could explain why compound action potentials are reduced, and this may be related to the impaired speech recognition and the decline in temporal resolving abilities common in this type of hearing impairment (Gates and Mills, 2005). A fourth subtype, *cochlear conductive presbycusis* is probably more hypothetical than clinical, and its mechanism could be related to stiffening of basilar membrane. Schuknecht and Gacek (1993) have added two subtypes, *mixed* and *indeterminate presbycusis*, and they state that most cases may be of the mixed type.

There is strong evidence that hereditary factors influence the presbycusis (McMahon et al. 2008). Both maternal and paternal hereditary patterns seems to exist. Mutations in the genes that encode proteins that participate in deactivating radical oxygen species have been associated with age-related hearing impairment. Mitochondrial deoxyribonucleic acid (DNA) is sensitive to radical oxygen species, and mutations in mitochondrial DNA have been identified in temporal bone specimens from patients with presbycusis. Therefore, it is likely some of the age-related hearing impairment is caused by oxidative stress, and that the degree of sensitivity to age-related hearing impairment is hereditary (Liu and Yan, 2007). Several familial mutations have been associated with late onset hearing impairment, but their relevance on a population basis may be limited (van Eyken et al. 2007). Duck et al. (1997) have reported a significant association between arterial hypertension, diabetes and presbycusis.

The association between nutrition and presbycusis has received only little attention. Consumption of omega-3 fatty acids and fish is associated with better hearing at the age of 50 years and above (Gopinath et al. 2010). High levels of very long-chain n-3 polyunsaturated fatty acids in the plasma are also associated with a slower progression of hearing impairment at lower frequencies (0.5, 1 and 2 kHz) (Dullemeijer et al. 2010).

Aging not only affects inner ear but also the central nervous system and auditory processing. The hearing in a noisy and reverberant environment is especially strongly affected. The impact of age on the temporal processing of auditory information is independent of hearing impairment (Pichora-Fuller & Souza 2003). The tasks that require auditory temporal processing are gap detection, temporal sequencing, and duration discrimination. These are important functions for identifying speech contrasts, speech recognition in difficult listening environments, and in situations where the speed of the speech is increased.

Central auditory processing disorders with or without a hearing impairment have a clear impact on self-reported hearing in the elderly (Jerger et al. 1990). These disorders are twice more common in male subjects compared to female subjects and its risk increases by 4 - 9% per year in elderly subjects with normal hearing (Golding et al. 2006). The exact prevalence of central auditory processing disorders is difficult to estimate, but it is very common in the elderly, and seems to be part of normal aging (Golding et al. 2004).

Alzheimer's disease affects significantly central auditory processing (Strouse et al. 1995). The clinical prevalence of Alzheimer's disease in the Finnish population aged 85 years or more is 16%; in an autopsy study postmortem findings compatible with Alzheimer's disease were present in 33% (Polvikoski et al. 2001). Hearing impairment seems to be associated with a loss of cognitive function and even dementia. A strong interdependence between hearing impairment and lower scores in the Mini-Mental State Examination (MMSE) independent of age and education have been reported in an Italian population of persons aged 65 years and above (Cacciatore et al. 1999). There was an increased risk of all-cause dementia in patients with hearing impairment in a follow-up study of 11.9 years involving 639 subjects between 36 and 90 years of age (Lin et al. 2011a). Also, subjects with hearing impairment have a more rapid and profound decline in their cognitive performance than controls with normal hearing (Lin et al. 2011b). An increase in hearing impairment of 25 dB $BEHL_{0.5\text{-}4\,kHz}$ is associated with a decline equivalent to about 6 years of aging in tests of naming colors and connecting consecutive numbers with lines. These observations may be explained by a shared pathologic etiology, the effects of hearing impairment on cognitive load and cognitive reserve, and/or the effects of social isolation and loneliness. In a Japanese population, a correlation between rising hearing thresholds and decreasing MMSE scores have been reported (Sugawara et al. 2011). The mechanisms of this phenomenon and the effects of rehabilitation, if any, need to be ascertained.

2.1.2 Prevalence

The literature on hearing impairment among adults was evaluated in a Nordic – British joint project (2001). Prevalence studies on hearing impairment among adults in United Kingdom and the Nordic countries met strict scientific criteria only rarely, and many studies that are locally and regionally of relevance cannot be generalized to larger populations. Many of the studies evaluated hearing impairment only by subjective means and in other studies selected populations were studied.

Uimonen et al. (1999) reported that the prevalence of measured hearing impairment was 10.0% among Finnish subjects aged 65 years and 32.5% among subjects aged 75 years, if the older WHO-definition of hearing impairment ($BEHL_{0.5\text{-}2\ kHz}$) was used. The EUWG-definition yielded prevalences of 37.2% and 64.5%, respectively. The study was population-based and 430 subjects aged 65 years and 382 aged 75 years were studied.

In a Swedish study Rosenhall et al. (1987) used a self-report method in a large scale study involving about 6000 subjects aged 65-74 years and about 4000 subjects aged 75- 84 years. The participants were interviewed and were asked the following question to identify hearing impairment: "Can you hear without difficulty what is said in a conversation between several persons, with or without a hearing aid?". The prevalence of hearing impairment was 23% in the age group 65-74 years and 30% in the age group 75-84 years. Males had significantly more often hearing impairment than females in both age groups.

Davis (1989) reported a prevalence of 60.2% of hearing impairment of at least 25 dB of the better ear in the age group 71-80 years [pure tone average of frequencies 0.5, 1, 2 and 4 kHz ($PTA_{0.5\text{-}4\ kHz}$)] in Great Britain.

Corna et al. (2009) used a self-report method to detect corrected and uncorrected hearing impairment in Canada. In two large population-based studies in 1994 and 2001 (17,262 and 130,827 respondents, respectively) five questions were used to assess the hearing ability of the subject. The questions concerned the ability of the subjects to hear a conversation with one person or at least three persons with or without a hearing aid, and if the subject heard at all. The overall prevalence of corrected hearing impairment was 6.5% in 1994 and 5.7% in 2001, and of uncorrected 4.0% and 2.5% in the adult population. In the age group 65-74 years the prevalence of corrected hearing impairment was 35.9%, and of uncorrected 26.9%. The prevalence of corrected and uncorrected hearing impairment in the elderly over 75 years was 37.6% and 42.1%, respectively.

Hearing among 75-year-old was studied in three Nordic areas by Hietanen et al. (2005). In Gothenburg, Sweden, and Glostrup, Denmark, the study population consisted of a random age cohort sample, and in Jyväskylä, Finland, of the entire age cohort. The participation rate in audiometric testing was 45%, 60% and 75%, respectively. The EUWG's definition of the degree of hearing impairment was used. It turned out that only 8.0%, 20.9% and 10.2% of males, and 33.9%, 29.0% and 24.5% of females were regarded as having normal hearing ($BEHL_{0.5\text{-}4\,kHz}$), in the three areas, respectively. About half of the subjects had mild hearing impairment, 30% of males and 20% of females had moderate hearing impairment, and severe to profound hearing impairment was a rarity. Self-reported hearing difficulties were reported among 57%, 42% and 41% of the males, and among 28%, 37% and 37% of the females, respectively. Speech recognition thresholds were better among Danish men compared to the other areas, but among women there was no statistical difference. The value of these findings concerning speech recognition is questionable, because the tests are not directly comparable from language to language.

Table 2. Studies on prevalence on hearing impairment (BEHL: Better Ear hearing Level)

Study	Location	Definition	Prevalence		Age/years
Uimonen et al. 1999	Finland	$BEHL_{0.5\text{-}4\,kHz}$>20 dB	10.0		65
			32.5		75
Rosenhall et al. 1989	Sweden	Self report	23		65-74
			30		75-84
Davis 1989	Great Britain	$BEHL_{0.5\text{-}4\,kHz}$>25 dB	60.2		71-80
Corna et al. 2009	Canada	Self report	62.8		65-74
			79.7		>75
Hietanen et al. 2005		$BEHL_{0.5\text{-}4\,kHz}$>20 dB	men	women	75
	Denmark		79.1	71.0	
	Finland		89.8	75.5	
	Sweden		92.0	66.1	
Hietanen et al. 2005		Self report	men	women	75
	Denmark		42	37	
	Finland		41	37	
	Sweden		57	28	
Mitchell et al. 2011	Australia	$BEHL_{0,5\text{-}4\,kHz}$>25 dB	men	women	
			28.7	17.0	60-69
			55.0	45.2	70-79
			79.0	77.7	80-89

In the Blue Mountains Hearing Study in Australia (Mitchell et al. 2011) the prevalence of hearing impairment (>25 dB $BEHL_{0,5\text{-}4\,kHz}$) by pure tone audiometry was among females aged 60-69 years 17.0%, females aged 70-79 years 45.2% and females aged 80-89 years 77.7%, and 28.7%, 55.0% and 79.0% among males, respectively. The sample size was 2238.

The prevalence of hearing impairment among the elderly is high, although the exact values differ significantly by the definition of hearing impairment and by the population. It is likely that the prevalence patterns will also change in the future, as lifetime noise exposure, nutrition, medications, and effects of ear infections change, but the body of evidence is lacking, so far.

2.1.3 Progression of presbycusis

According to several cross-sectional studies, hearing impairment is more prevalent with advancing age (Uimonen et al. 1999, Rosenhall et al. 1987, Corna et al. 2009). There are also some studies that have followed the natural course of hearing impairment and tried to estimate annual deterioration rate of hearing.

Jönsson et al. (1998) have evaluated the progression of hearing impairment between the age of 70 and 75 years in five different cohorts. The mean curves of audiometric pure tone thresholds were down-sloping, as expected. Male subjects had steeper sloping curves, and the difference between males and females was greatest at 4 kHz and increased with age (15 dB and 24 dB at 4 kHz in 70 and 75 years, respectively). The average annual decline of pure tone thresholds was greatest at 2 and 4 kHz among males (2.8 and 2.9 dB/year, respectively) and at 4 and 8 kHz (1 and 1.3 dB/year) among females. The steeply sloping audiograms among males is probably due to males being more exposed to noise during their professional lives and service in armed forces.

Jönsson and Rosenhall (1998) have studied older age groups in a similar study. In a longitudinal cohort study they observed less decline in pure tone thresholds between ages 80 to 90 years than between ages 70 to 80 years. The authors propose that longevity is associated with a biological advantage which could explain the slower decline in hearing among octogenarians compared to septuagenarians.

Gates and Cooper (1991) did a 6 year follow-up study where the subjects were initially 58 to 88 years old. They found two common patterns of hearing impairment, one at low (250-1000 Hz) and the other at high (4-8 kHz) frequencies. The low frequency type worsened at an increasing rate with age, and women had a faster worsening rate in this group. The high frequency type had a slower deterioration rate for older subjects; poor hearing at the outset did not deteriorate as fast as a better hearing, and there was no gender difference. The authors explain this difference between hearing patterns by a different pathophysiology in these groups: hair cell degeneration could cause high frequency hearing impairment, and strial atrophy or other cochlear process low frequency impairment.

In a longitudinal study with shorter follow-up, Davis et al. (1990) reported a median deterioration rate of hearing of 5-6 dB per decade. The deterioration rate for subjects over 55 years was 9 dB per decade and 3 dB per decade among younger subjects. However, the short follow-up interval of two to eight years leaves room for uncertainty, as the accuracy of psychoacoustic hearing threshold measurements is of the same order as the changes in hearing reported by the authors.

Mitchell et al. (2011) followed up subjects with an initial hearing impairment (>25 dB $BEHL_{0.5\text{-}4\ kHz}$) for five years. The short follow-up time did not enable exact evaluation of hearing worsening in terms of dB/year. Instead, they used the percentage of subjects that had a decline of more than 10 dB $BEHL_{0.5\text{-}4\ kHz}$ as a measure. For the age groups 60-69, 70-79 and 80-89 years, progression of >10 dB was recorded among 11.1%, 16.6% and 21.7%, respectively, and there was no significant difference between genders.

The small sample sizes and short follow-up times limit substantially the usefulness of these studies. However, these studies and clinical evidence do indicate that hearing thresholds increase with aging.

2.1.4 Rehabilitation

Hearing aids

Hearing aids are sound amplifiers that are personally fitted to a patient with hearing impairment. Three basic types of hearing aids are available: in-the-ear (ITE), behind-the-ear (BTE) and body worn hearing aids. The body of an ITE hearing aid is custom-made to fit the patient's ear canal, and the electronics are embedded in the body. In BTE hearing aids the electronics are located in the body of the hearing aid which is worn behind the auricle so that one or two microphones are located in the uppermost part of the hearing aid above the ear lobe. The sound is led to the ear canal through a tube, and a custom-made ear mould keeps the hearing aid in place on the ear and prevents acoustic feedback. An alternative model of a BTE hearing aid has a receiver in the ear (RITE) which is embedded in an ear mould. Instead of a tube, there is an electric wire connecting the hearing aid and the receiver in the ear mould. So called open fitting is also possible for patients with mild high frequency hearing impairment: a thin tube transfers the sound from a BTE hearing aid, and the ear mould is commonly replaced by an ”off-the-shelf” open tip. Body worn hearing aids are no longer used very often, because their additional maximum output of sound compared to modern BTE hearing aids only rarely improves the speech understanding. (Bentler & Mueller 2009)

Digital sound processing techniques were introduced into hearing aids in the 1990's, and nowadays almost all hearing aids in Finland are digitally programmable and provide different levels of adaptive amplification, feedback control and adaptive microphone techniques. The volume control wheel is no longer necessary, as the hearing aid adapts rapidly to changes in the sound environment. The control switch that was used to switch on and off the hearing aid and to move into inductive listening is often replaced by a circuit breaker in the lock of the battery compartment, and a different knob is available for changing programs (e.g., inductive listening and situational programs). Programming of the hearing aids is based on audiometric measures of the patient and can be fine-tuned to an optimal response to the patient's needs. (Bentler and Mueller 2009) Although there are several studies on the benefits of hearing aids and on the use of hearing aids, momentum leaps in the advances of hearing aid technology make it difficult to make generalizations of these studies to reflect the situation today.

The hearing aids have a remarkable effect on the hearing-related quality of life and communication skills of elderly people. Mulrow et al. (1990) performed a randomized trial involving 194 elderly veterans with a hearing impairment. Of them, 95 received hearing aids immediately and 99 were assigned to the waiting list. The former group reported a significant improvement at four months after hearing aid fitting of social and emotional function, communication (Quantified Denver Scale of Communication Function), cognitive function (Short Portable Mental Status Questionnaire) and even depression (Geriatric Depression Scale). The average self-reported hearing aid use was 8 hours daily. At follow-up one year later (Mulrow et al. 1992) the quality of life variables were still improved except for cognitive ability, which had reverted to baseline.

The effect of hearing aid on cognitive ability was not confirmed in another study (van Hooren et al. 2005). The results of neurocognitive tests before and one year after hearing aid fitting (56 patients, mean age 72.5 years) remained the same, although aided hearing thresholds improved compared to the unaided situation. This finding is not surprising and is in agreement with Mulrow's follow-up (1992) study. Although the functional cognitive performance will probably improve in everyday life as the effect of mishearing is reduced, it is most unlikely that the organic causes affecting the patient's cognitive functions will be affected.

Parving and Philip (1991) used a questionnaire to study hearing aid use and the benefits for patients over 90 years of age. Even in this age group the benefits were clear. Half of the respondents (35% drop out rate) used the hearing aid every day and 64% were satisfied. Not surprisingly, these elderly subjects had some problems related to handling of the device, and this was especially common among first-time users. Schneider et al. (2010) reported a significant increase in the need of community support in the hearing impaired group, especially if the hearing impaired subject did not use a hearing aid. Although the study population was large (N=2956), the number of persons who actually needed support was small (N=138). The subjects with hearing impairment were older than the control group. Multivariate analysis adjusted for age, sex, living status, self-rated poor health, hospital admissions in the past year, walking disability and best-corrected visual impairment showed that the prevalence of support by the community was higher in mildly hearing impaired group and overall hearing impairment group but not among those with a hearing impairment of >40 dB $BEHL_{0.5\text{-}4\ kHz}$. The incidence of need of community services during five years of follow-up did not differ significantly between persons with normal and persons with impaired hearing.

Hearing aid compliance

Sorri et al. (1984) have interviewed 150 hearing-impaired Finnish subjects two years after fitting of a hearing aid. It turned out that 23% of the subjects used the hearing aid seldom or never, 19% occasionally and 57% used every day. Behind-the-ear aids were used more often than body-worn aids. Poor compliance was associated with mild and sensorineural hearing impairment. When asked about the infrequent use of hearing aids, the non-users claimed that they had only little opportunity to converse with others. Nevertheless, the number of social contacts did not differ from the regular users. The non-users had poor skills in handling of the hearing aid. The hearing aids in the beginning of 1980's had all analogue signal processing. In a new study with same methods twenty years later (Vuorialho et al. 2006) the investigators reported a remarkable improvement in the use of hearing aids: The proportion of non-users decreased from 23.4% to 5.3%. Satisfaction with the availability and quality of counseling for advice on how to use hearing aids had also improved, and the patients themselves had better user skills.

Lupsakko et al. (2005) studied the use of hearing aids in a sample of subjects over 75 years in Kuopio, Finland. Of the 95 subjects that had a hearing aid, 55% were full time users, 20% part-time users and 25% non-users. The non-users had lower income, their score in MMSE was lower, and they had lower score in the Activities of Daily Living scale. The most common reason for non-use was no need for a hearing aid (42%), 21% felt that they were not able to use a hearing aid, and 17% reported that their hearing aid was broken.

The association between impaired cognitive abilities and hearing aid non-use is an important finding. These patients have less capacity to compensate for their hearing impairment by central processing, and they need better hearing to cope with everyday life. Support methods to improve hearing aid use (help in getting the hearing aid in the ear, and device maintenance) need to be considered with relatives or nursing staff.

In a review article by Knudsen et al. (2010) there was no significant association between hearing aid use and the source of motivation for hearing rehabilitation (self or others). Hickson et al. (1999) found that patients were more satisfied with their hearing aids if the motivation for hearing aid fitting came from themselves rather than from others. There is discrepancy in the literature whether the attitude towards hearing aids before actual fitting of the device has an effect on hearing aid use and satisfaction (Knudsen et al, 2010). The article summarized that there were three studies that supported a connection between acceptance of using a hearing aid and the patient's acceptance of having impaired hearing, problem awareness and subjective distress caused by poor hearing.

Stigma of hearing impairment and using a hearing aid

Wallhagen (2010) has studied the stigma of hearing impairment and hearing aid by interviewing older adults with a hearing impairment and their spouses at baseline, at three months and at one year during the hearing rehabilitation process. The survey was completed by 84 dyads. It was found that three important experiences of stigma could be found: *altered self-perception, agism and vanity.*

Most people perceive themselves as ”normal”, and a change in this perception, e.g., integration of disability into one's self-perception, poses a challenge. Some subjects were willing to accept the embarrassment caused by mishearing rather than to recognize their hearing impairment. The hearing impairment is often thought as a sign of getting old, and hearing impairment and hearing aid are strong symbols and reminders of higher age for the patient, the spouse and community. The fear of agism can prevent rehabilitation and the patient may lose an opportunity of improving her quality of life. According to Wallhagen, the fear of being less attractive (i.e., vanity) is a common reason for reluctance against hearing rehabilitation. Time will show if improved cosmetic appearance of hearing aids, and the common use of in-the-ear devices, such as hands-free systems of mobile phones, increase the use of hearing aids in the future.

Comorbidity and its effect on rehabilitation

The loss of vision significantly increases the disability caused by hearing impairment. The impairment in communication is enhanced if the patient loses both visual methods of communication (reading and lip reading) and hearing of speech. The loss of auditive information of space and direction causes problems in orientation for a person with severe loss of visual acuity. Lupsakko et al. (2002a) report that 7% of subjects over 75 years in Finland have combined visual and hearing impairment. The most common causes for visual impairment among the elderly are cataracts and retinopathy. Depressive symptoms (but not clinical depression) were more common in the group of patients with combined sensory impairment (Lupsakko et al. 2002b). Keeping in mind that not only communication but also pastime are effected by severe combined disability, this observation does not come as a surprise.

Patients with combined sensory impairment need special care in hearing rehabilitation. The visual impairment has to be taken into account when choosing hearing aids, as the maintenance and handling are more difficult with poor vision. Binaural hearing aid fitting is likely to improve the spatial and directional awareness (Noble, 2010).

Diseases that cause dementia (e.g., Alzheimer's disease) affect cognition and add to the disability caused by hearing impairment. These patients do not seek help for their hearing impairment, and their hearing impairment goes often undiagnosed and untreated

(Cohen-Mansfield & Taylor, 2004). There is some evidence (Allen et al. 2003) that fitting a hearing aid for patients with hearing impairment and dementia in nursing homes improves the functional capabilities, not only the hearing, of the patients. Over half of the patients used their hearing aids still six months after fitting. As the decline in cognitive function impairs handling and service of the hearing aids, application of the hearing aid in the ear and maintenance may have to be delegated to relatives or nurses.

Other technical means of rehabilitation

Cochlear implantations have been successful also in elderly (Labadie et al. 2000). There was no significant difference between middle aged and elderly persons with cochlear implants as regards recognition of sentences and monosyllabic words. Cochlear implants are nowadays used routinely for elderly persons with severe or profound hearing impairment, if other measures are not adequate. Nevertheless, the overall health and cognitive level of the patient have to be adequate to warrant the expensive and demanding rehabilitation incurred by cochlear implants.

There are several kinds of assistive listening devices that are used either to replace hearing aids or to enhance their function. Hearing aids can be combined with a transmitter that sends the signal to a receiver in the form of a radio frequency signal; the BlueTooth™-technique may also be used. These instruments improve the signal-to-noise ratio in meetings and lectures. It is possible to send the acoustic signal from a radio or television set to the hearing aid by using induction loops or streamers specific for hearing aids. Conventional portable amplifiers with on-the-ear earphones are used if the patient does not want a hearing aid or is not capable of using it. The need for such amplifiers has diminished as the hearing aids have improved, and become easier to handle.

Aural rehabilitation and counseling

Several non-technical methods of rehabilitation are used to help the patient to cope with a hearing impairment. In a review article (Hawkins 2005) there were 12 studies that assessed personal adjustment to hearing impairment, perceived hearing handicap, or hearing aid benefit and/or satisfaction after counseling. The counsel consisted of aural rehabilitation programs in adult groups. There was reasonably good evidence that participation in an adult aural rehabilitation program provides a reduction in self-perception of the hearing handicap for a short time and that communication strategies and hearing aids might be used more appropriately. The duration of the benefit is unknown. Speech-reading abilities can be improved with training (Strelnikov et al. 2009), and speech-reading enhances communication in noisy environments and when the hearing impairment is advanced. Counseling should also include adequate information on the social support provided by the community for the patients with a hearing impairment.

2.2 Questionnaires in hearing impairment epidemiology

2.2.1 Unstandardized questionnaires and self-report methods

Rosenhall et al. (1987) used an unstandardized questionnaire in a longitudinal study that was a part of the Gerontological and Geriatric Population Study in Gothenburg, Sweden. They asked the subjects to classify their hearing as normal, slightly impaired or severely impaired, and what the amount of hearing problems the subjects experienced (continuous, slight to moderate, or no problems). Problems in conversing with one person and with many persons were asked. Separate questions addressed the difficulties in hearing radio, television, the doorbell and the telephone. There was also a set of questions on tinnitus: no tinnitus, occasional problems or continuous serious tinnitus. Interestingly and of note is that there was no alternative for continuous non-disturbing tinnitus. The questions were presented by a nurse who interviewed the participants. The validity of the method was not ascertained by a test-retest analysis which needs to be kept in mind. Rosenhall et al. (1999) have later used a one-question method to estimate hearing impairment (”Can you hear without difficulty what is said in a conversation between several persons, with or without using a hearing aid?”). There was no comparison between the replies to the question and the measured hearing thresholds.

Davis (1991) used a classifying self-report method to estimate the prevalence of hearing impairment. He asked the subjects whether they had difficulties in hearing, and the alternatives were no difficulties, great difficulty in noise, and slight, moderate or severe difficulty in quiet. Davis highlights the difference in hearing levels and the self-reported hearing difficulties in different age groups. The disability among younger (28-59 years) subjects was significantly greater than among older (60-79 years) subjects for a given hearing impairment.

Several studies have been done to establish one good question for assessment of hearing impairment. ”Would you say that you have any difficulty hearing?” had a sensitivity of 51% and a specificity of 88% among women 60-85 years of age (Clark et al. 1991). The question ”Do you feel you have a hearing loss?” had a sensitivity and specificity of 71% in identifying a hearing impairment in a sample of subjects at 48-92 years in Beaver Dam, USA (Nondahl et al. 1998). A limit of $PTA_{0,5\text{-}4\ kHz}$ >25 dB in the worse ear was the criterion for hearing impairment in this study. This low limit could explain the low sensitivity, and especially the finding that subjects older than 65 years had even lower sensitivity. ”Do you feel you have a hearing loss?” was also compared to audiometry in a study by Torre et al. (2006). They used a limit of >25 dB $PTA_{0.5\text{-}4\ kHz}$ in the worse ear for hearing impairment, and reported a sensitivity of 76% and a specificity of 73% in a sample that had a self-reported prevalence of hearing impairment of 58%. Lutman (1990) observed that self-reported disability was under-rated by older subjects with mild impairment, and that there was only a poor correlation between self-reported hearing impairment and the results of performance tests, such as words in quiet and sentences in noise.

Hannula et al. (2011) compared self-reported hearing problems with the measured hearing levels in a random sample of older adults aged 54-66 years. Two questions were presented concerning hearing difficulties (Question 1: Do you have any difficulty with your hearing? Question 2: Do you find it very difficult to follow a conversation if there is background noise, e.g. TV, radio, children playing?), and the results were compared to the $PTA_{0,5\text{-}4\ kHz}$-value of the better and the worse ear. Prevalences of 37% for hearing difficulties and of 43% for difficulties in following a conversation in noise were reported. The mean hearing levels in the better ear of the subjects that had hearing difficulties were surprisingly low (for men 23.4 dB and 21.9 dB, and for women 19.3 dB and 16.9 dB for question 1 and question 2, respectively). A majority of the subjects with hearing difficulties had a hearing regarded as normal according to WHO's definition of hearing impairment.

2.2.2 Standardized questionnaires

The Hearing Handicap Inventory for Elderly (HHIE) was created for evaluation of the effectiveness of hearing aid rehabilitation (Ventry & Weinstein, 1982). The original HHIE is a 25 item questionnaire, and the maximum total score is 100. The "always" response scores 4, "sometimes" as 2, and "never" as 0. The shorter screening version (HHIE-S) (launched in 1986) was created by selecting ten questions from HHIE to assess the emotional and social aspects of hearing impairment. The emotional and social scores are seldom used, at least in published studies. The same scoring system is used in the HHIE-S as in the HHIE, and the maximum total score is therefore 40. The American Speech-Language-Hearing Associations draft guidelines (1997) suggest a total HHIE-S score >8 as indicating the presence of hearing handicap. Lichtenstein et al. (1988a) evaluated the HHIE-S against five different definitions of hearing impairment, and reported sensitivity values ranging from 53% to 72% and specificity values from 70% to 84%. The HHIE-S was regarded as a valid and robust test for identifying hearing impairment in the elderly.

Wiley et al. (2000) observed in their study on the relation between HHIE-S, measured pure tone thresholds and word recognition scores that the probability of reporting a hearing disability decreased with age (data were adjusted for the degree of hearing impairment). As a part of the Blue Mountains Hearing Study (BMHS) (Sindhusake et al. 2001) the HHIE-S was compared to a single question ("Do you feel you have a hearing loss?") for detecting hearing impairment in the age group 55-99 years. The single question was able to detect mild hearing impairments of >25 dB $PTA_{0,5\text{-}4\ kHz}$ better than the HHIE-S. However, the HHIE-S was better at identifying hearing impairment of at least moderate (>40 dB $PTA_{0,5\text{-}4\ kHz}$) degree. The results of the single question questionnaire were not affected by age or gender. The HHIE-S yielded better results in younger than older female subjects.

The sensitivity and specificity of the HHIE-S and four questions on hearing were evaluated in the Epidemiology of Hearing Loss Study (EHLS, Nondahl et al. 1998). In the study, a limit of $PTA_{0,5\text{-}4\ kHz}$ >25 dB was used for the worse ear as the criterion for hearing impairment. This relatively low limit (especially since it concerned the worse ear) may explain the finding of a low sensitivity for the HHIE-S: at the cut-off score of >8 sensitivity was 34% and specificity 95%.

The Hearing Handicap Inventory for Adults (HHIA) is a modified version of the Hearing Handicap Inventory for the Elderly, and it is intended to be used with individuals aged less than 65 years (Newman et al, 1991). Three items from the original HHIE questionnaire have been modified to include the items created to identify the effects of hearing impairment on occupational performance. A similar screening version to the HHIE-S was also developed, but it seems that there are no published reports on the use of it.

Table 3. Studies on sensitivity-specificity characteristics of Hearing Handicap Inventory for Elderly - screening (HHIE-S) in detecting hearing impairment. BEHL Better Ear Hearing Level, WEHL Worse Ear Hearing Level, SRT Speech Reception Threshold

Study	Age (years) Location	Definition of hearing impairment	Sensitivity %	Specificity %
Sindhusake et al. 2001	55-95 Australia	>25 dB $BEHL_{0,5\text{-}4\ kHz}$	58	85
		>40 dB $BEHL_{0,5\text{-}4\ kHz}$	80	76
		>60 dB $BEHL_{0,5\text{-}4\ kHz}$	100	70
Nondahl et al. 1998	43-84 USA	$WEHL_{0,5\text{-}4\ kHz}$ >25 dB	34	95
Lichtenstein et al. 1988	>65 USA	>40 dB 1 or 2 kHz in both ears, or on 1 and 2 kHz in one ear	72	77
		>25 dB $BEHL_{0,5\text{-}2\ kHz}$	66	79
		>25 dB $BEHL_{1.2.4\ kHz}$	53	84
		SRT >25 dB	62	72
		Speech recognition <90%	63	72

Lamb et al. (1983) developed a questionnaire to evaluate hearing among adults, the Hearing Performance Inventory (HPI). A revised version of this questionnaire has 90 items that consider understanding speech with and without visual cues, the effect of environmental sounds, response to auditory failure, and personal, social and occupational aspects of hearing. The amount of items and the inclusion of occupational items make this inventory less suitable for screening among elderly subjects, and it has apparently not been used for epidemiological purposes.

2.3 Tinnitus

2.3.1 Mechanisms of tinnitus

Tinnitus is defined as a sound perception without an external source of sound, and it is usually divided into objective and subjective subtypes. If the sound is detectable by another observer, usually by auscultation, it is called objective tinnitus. Objective tinnitus may be caused by arteriovenous fistulas, dural hemangiomas, atherosclerotic lesions of the arteries of the head and neck, middle ear muscles, and crepitation of the temporomandibular joint or joints of the cervical spine.

Subjective tinnitus is perceived only by the patient. (Tyler et al. 2009) Subjective tinnitus is typically associated with hearing impairment, and the tinnitus sound is often near or at the same frequencies where the patient has his or her hearing impairment (e.g., high frequency hearing impairment and peeping tinnitus). Typically, steep high-frequency hearing impairment is associated with a peeping tonal perception, and flat or low frequency hearing impairment is accompanied with noise-like tinnitus. (Pan et al. 2009)

Several mechanisms may explain the origin of subjective tinnitus. Cochlear damage and hearing impairment due to almost any cause (noise, ototoxic agents, aging etc.) can be associated with tinnitus. Terao et al. (2011) reported significantly more damage in the outer hair cells and stria vascularis in histological samples of the temporal bones of eight patients with presbycusis and tinnitus compared to eight patients with presbycusis only. There were, however, no differences in degeneration in the inner hair cells or cells of the spiral ganglion. The source of tinnitus perception may in rare cases reside in the inner ear, and especially the outer hair cells. Spontaneous otoacoustic emissions (SOAE) can be detected occasionally in patients with tinnitus; these SOAEs occur in the same frequency region as the tinnitus. This might be due to a spontaneous activity in the outer hair cells. Kim et al. (2011) have reported that subjects with matching SOAE and tinnitus have a tendency for higher Tinnitus Handicap Inventory (THI) scores, a more quiet tinnitus measured by loudness matching, and higher transient evoked and distortion product otoacoustic emissions. However, SOAEs are common also among subjects without tinnitus.

The modern methods for imaging functional changes in the brain (e.g., positron emission tomography and functional magnetic resonance imaging) have led to the concept that tinnitus is often generated in neural auditory system. Still, there is tinnitus-related neuronal activity also outside auditory system, e.g., in the limbic system and frontal cerebral areas (Lanting et al. 2009). Melcher et al. (2009) reported that there is increased stimulus evoked activation in the inferior colliculi among subjects with tinnitus. Adding a low frequency noise resulted in reduced activity of the tinnitus group, but not in the non-tinnitus group. There is, hence, some evidence that tinnitus patients have elevated sound evoked activity in the midbrain, but the source of this activity may also be peripheral to this.

Jastreboff and Hazel (1993) have presented a neurophysiological model of tinnitus: The neural signal generated in the auditory tracts is perceived in the auditory cortex as sound. If the sound perception is classified as annoying, the limbic system (responsible for arousal) becomes activated, and a feedback loop is formed. Annoyance results in increased alertness, and the patient focuses on the tinnitus sound, which increases the annoyance. The spontaneous activity of the auditory tracts results in phantom sound perception, increased arousal and increased distress.

McKee and Stephens (1992) compared young patients with tinnitus and normal hearing with subjects without tinnitus. High-frequency audiometry results did not differ significantly, nor did the brainstem auditory evoked potentials, but otoacoustic emissions were more often absent in the tinnitus group than the non-tinnitus group. The standardized questionnaire Crown-Crisp Experiental Inventory was used to identify any neurotic symptoms the subjects may have had. The subjects with tinnitus had significantly higher scores in free floating anxiety, obsessionality and somatic anxiety, this was especially true for the male subjects. Although the sample was small (18 patients, 19 in control group), there were two important findings: Firstly, the impaired otoacoustic emissions may indicate minor defects in the cochlea, which thus may be the somatic source for the tinnitus. Secondly, increased sensitivity to tinnitus is associated with certain personality traits and psychiatric comorbidity.

2.3.2 Prevalence of tinnitus

Tinnitus is very common. Oron et al. (2011) reported that 76% of unselected adults have had at least one brief episode of tapering, unilateral tinnitus. The subjects that had perceived such phenomenon reported that such attacks occurred once a month with a typical duration of 25 seconds. Heller and Bergman (1953) report in their classical study that 94% of the subjects with no tinnitus experience, in fact, had a tinnitus-like perception in a sound proof room.

In a review article by Sanchez (2004) the prevalence of tinnitus in ten studies is scrutinized. The prevalence is 3 to 30% in various adult populations. As the risk for hearing impairment increases with advancing age, and as tinnitus is often associated with hearing impairment, the prevalence of tinnitus rises with age. Rosenhall and Karlsson (1991) reported a prevalence of tinnitus of 29% among persons aged 70 years in Gothenburg, Sweden. Their question was ”Do you hear buzzing sound?”.

The prevalence of tinnitus among older adults was studied as a part of Blue Mountains Hearing Study (BMHS) in Australia (Sindhusake et al. 2003a). In this population-based study the questions that were asked were related to the presence and degree of annoyance of tinnitus, any tinnitus treatments, and the treatment results. The results were compared to audiometric data. Age did not have any significant effect on the prevalence of tinnitus, and tinnitus was equally common in both genders. The age group of 70-79 years had a tinnitus prevalence of 30%, and among subjects over 80 years the prevalence was 25%. The mean age adjusted hearing was poorer in subjects with tinnitus. The tinnitus was regarded as very or extremely annoying by 16% of the subjects, as mildly annoying by 50%, and as not annoying by 33%. About 3% of the patients reported that the tinnitus kept them awake or made them often distressed. The quality of life of the same population was evaluated with 36-item Short-Form Health Survey (SF-36) (Gopinath et al. 2010). The subjects with tinnitus scored lower in the components concerning bodily pain, vitality, social function, role limitation caused by emotional problems, and mental health. These subjects had also significantly lower compound mental health scores, while the compound physical health scores were similar to peers.

Sataloff et al. (1987) reported a prevalence of tinnitus of 24% among 57-92 years old. Their question was ”Do you have noises in your ears”. The attendants in this study (N=267) were healthy and they had no noise exposure, drugs, ear infections or surgery, diabetes, angina or high blood pressure. These stringent exclusion criteria were applied to identify true, primary tinnitus. Primary tinnitus is usually defined as tinnitus for no detectable cause, not even cochlear degeneration. According to the definition used in this study, the tinnitus associated with presbycusis was ”primary”. The highly selected population sample may lead to low external validity of the results.

2.3.3 Tinnitus and mental health

The interaction between mental health and tinnitus is studied only little, and almost nothing is known on this subject among elderly. The association between depression and tinnitus has been identified in several studies. Folmer et al. (1999) found no difference in tinnitus loudness between tinnitus patients with and without depression. The patients with current depression described the tinnitus as significantly more annoying on all 12 questions compared to non-depressed subjects. Gopinath et al. (2010) reported that the risk of depression (measured with the Mental Health Index) was 1.9 times higher among persons with tinnitus of recent onset and 2.0 times higher among persons with a long history of tinnitus compared to peers.

Krog et al. (2010) approached the relation of mental health and tinnitus in a population-based study in Norway. Participants with tinnitus scored significantly higher on anxiety and depression measures, and lower on self-esteem and well-being measures than people without tinnitus. In what the authors considered to be a “critical study”, Ooms et al. (2011) found a significant correlation between tinnitus and depressiveness measured with the Beck Depression Inventory (BDI). They claimed that the correlation was due to content overlap between the BDI and the Tinnitus Handicap Inventory.

The association between tinnitus and personality disorders has not received much attention. A distressed personality, negative affectivity and social inhibition seem to be associated with tinnitus (Bartels et al. 2010). Personality disorders are associated with anxiety and depression, and it is likely that some of the tinnitus patients do have personality disorders, but there are no facts.

Auditory hallucinations are typical for several types of psychoses. There is no reason to believe that psychosis would somehow prevent tinnitus, and tinnitus should be at least as common among psychotic patients as in the non-psychotic, healthy population. The association between tinnitus and psychotic diseases has not been studied, partly due to methodological hurdles: the patients are not often capable of differentiating between pure hallucinations and ”somatic” tinnitus, and the possibility of tinnitus is probably not recognized by the professionals. Popeo et al. (2011) present a case report of a patient with psychotic depression and severe tinnitus, which was successfully treated with electroconvulsive therapy. Marneros et al. (1997) describe a patient where imperative and commenting voice hallucinations were resolved after curative surgery for otosclerosis. The former patient represents the usual interaction between depression and tinnitus, while the latter is likely to be a misinterpretation by the psychotic patient of a constant tinnitus caused by otosclerosis. It is not likely that ear surgery changed the psychotic properties of the mind or brain. It is equally unlikely that the otosclerotic ear somehow produced a speech-like signal. The sound of tinnitus may be integrated as a part of psychotic construction by the patient’s brain. Another example of this is a paranoid patient (treated by the author, unpublished observation) who had high-frequency tinnitus that was interpreted by the patient as a certain sign of activity of a number of electric devices that were directed toward her brain. Vice versa, it is quite common for patients to fear that the tinnitus is driving them insane because they ”hear voices”. Cima et al.(2011) reported a significant association between the fear of the psychological consequences of tinnitus and an increased attention toward the tinnitus.

2.3.4 Tinnitus, somatization and alexithymia

The somatization disorders are described as pains in different parts of the body, gastrointestinal problems, and sexual or pseudoneurological symptoms which are not related to any medical condition (DSM-IV TR, 2000). Although there is often a clear somatic source for the perception of tinnitus, the annoyance caused by tinnitus has much in common with somatization.

Scott and Lindberg (2000) reported that help-seeking subjects with tinnitus differed from non-help-seeking tinnitus subjects and control subjects in that they had more often lower back pain, neck and shoulder pain, headache, sleep disorders and muscle tension. In their study, help-seeking tinnitus patients had a significantly higher score in State Anxiety Inventory Scale, Trait Anger Scale, Negative Mood Scale, Daily Hassel Scale and Epidemiological Studies Depression Scale. In the Life Orientation Test the help-seeking tinnitus group got lower scores than the other two groups. High values indicate a person with strong beliefs or expectancies regarding his or her own capacity.

The association between tinnitus and somatoform disorders was evaluated by Hiller et al. (1997). The overall prevalence of tinnitus was 11% in this study, and the patients with somatoform disorders had a prevalence of tinnitus of 42%. Of the patients with hypochondric disorder 27% had tinnitus. Tinnitus was more common than many other common symptoms among patients with somatoform disorders, and it was related to depression, anxiety and symptoms of autonomic arousal. The authors discuss the possibilities that tinnitus may be a somatoform symptom, since these two entities have substantial comorbidity. Alternatively, there may be some common mechanisms underlying tinnitus and somatoform symptoms. Also Newman et al. (1997) reported an association between emotional distress due to tinnitus and high self-attention and somatic attention measures. They state that attentional mechanisms are important for the perception of tinnitus.

Belli et al. (2008) made a case control study on psychiatric comorbidity with tinnitus. A standardized semistructured psychiatric interview (Structured Clinical Interview for DSM-IV, SCID-I, SCID-II), BDI, Beck Anxiety Inventory and the revised SCL-90-R were used. More than 25% of the tinnitus patients had at least one psychiatric diagnosis, and the prevalence of somatoform disorders was significantly higher than in a sex- and age-matched control group without tinnitus.

According to these studies, tinnitus has very much in common with somatoform disorders. Although there is a clear somatic source for the perception of tinnitus, the annoyance caused by tinnitus differs significantly from person to person even when the tinnitus has a seemingly similar etiology and measurable variables.

Sifneos (1973) coined the term alexithymia, “no words for feelings”. It has become one of the most interesting theoretical constructs in modern psychosomatic research. The typical features of alexithymia comprise difficulty in identifying and describing feelings, difficulty in distinguishing feelings from bodily sensations of emotional arousal, constricted fantasy life and an externally oriented cognitive style (Bagby and Taylor, 1997). Although the relation between alexithymia and a wide range of diseases and symptoms has been studied, tinnitus is an exception. The association between tinnitus and alexithymia is just not known.

2.3.5 Hearing impairment and tinnitus in elderly

The association between hearing impairment and tinnitus has been reported among 50–59-year-old subjects in Sweden: Of those that reported tinnitus, 71% also reported hearing impairment (Axelsson & Ringdahl 1989). The self-report method did not reveal the share of those that had minimal hearing impairment or higher hearing thresholds at frequencies that are less important for speech understanding. In the BMHS (Sindhusake et al. 2003b) poorer hearing thresholds were associated with tinnitus among 2015 adults aged 55-99 years reporting tinnitus. $BEHL_{0.5\text{-}4\,kHz}$ was 24.7 dB HL among those reporting tinnitus and 21.4 dB HL among those that did not, and similar results were found at higher frequencies (48.0 dB HL and 40.6 dB HL at $BEHL_{4,6,8\,kHz}$, respectively). Nondahl et al. (2002) reported that the 5-year incidence of tinnitus was 5.7 % in a population with an average age of 69.3 years. Hearing impairment at baseline was independently associated with tinnitus. There is an association between hearing impairment and aging, and between tinnitus and aging. Little is known about the effect of age on distress caused by tinnitus among the elderly.

2.3.6 Treatment of tinnitus

Treatment of tinnitus is challenging. The patients often hope that the annoying sound could be totally removed. This is seldom possible. Objective tinnitus with a vascular origin may sometimes be cured by surgery or embolization. A minority of patients with chronic subjective tinnitus may be helped with the treatment of the underlying hearing impairment (e.g. otosclerosis). There is some evidence that a cochlear implant can diminish tinnitus that is associated with hearing impairment (Olze et al. 2011), at least in some patients.

Jastreboff and Hazel created a standardized method for the treatment of tinnitus, Tinnitus Retraining Treatment (TRT) (Hazell, 1999). TRT is based on a neurophysiological model of tinnitus, and it includes educational counseling on the mechanism of tinnitus and adaptation to it in addition to sound therapy. The patients are divided into five groups (categories 0, 1, 2, 3 and 4) according to the severity of the tinnitus, the presence or absence of significant hearing impairment and the presence or absence of hyperacusis. Sound therapy is chosen according to the category of the patient, and the alternatives are environmental sound enrichment, sound generators, hearing aids or cochlear implants. Regular follow-up sessions are included in the protocol.

Phillips and McFerran (2010) evaluated the efficacy of TRT in a Cochrane analysis. Only one study (Henry et al. 2006) was found to focus on true TRT, several studies were excluded because they used modified versions of TRT. TRT seemed to have a significantly better effect on annoyance of tinnitus than unstandardized counseling and tinnitus maskers. There were several biasing factors in this study, and it was classified to be of low quality. A later study by Bauer and Brozoski (2011) have shown a beneficial effect of both TRT and general counseling. One might define TRT as a form of time and resource consuming treatment compared to general counseling. Studies on the negative effects of TRT (e.g., treatment as a reminder of the existence of tinnitus) have not been published.

Cognitive behavioral therapy (CBT) is a structured, time-limited form of psychotherapy which is usually offered on an outpatient basis including 8-24 weekly sessions. Behavioral and cognitive tasks are used to modify the patient's response to thoughts and situations. The theoretical basis of this treatment is that *core beliefs* originating from childhood events provide a pattern of reaction. Specific events or moods can reinforce these core beliefs and lead to behavioral and emotional responses. The aim of CBT is to generate an understanding of the link between thoughts and feelings arising from an event, and to use this information to understand one's own core beliefs and to modify cognitions and behavioral and cognitive responses. The patient and therapist view the patient's fearful thoughts as hypotheses that need to be critically examined and tested. CBT involves education, discussion of evidence for and against the beliefs, imagery modification, attentional manipulations, exposure to feared stimuli and relaxation techniques. Achievable goals are set for the treatment, and behavioral and cognitive assignments which test beliefs are used.

Martinez-Devesa et al. (2010) have published a Cochrane analysis on the effect of CBT on tinnitus. Eight studies were included, and no significant effect on loudness of tinnitus was found. However, the treatment had a significant effect on depression and the patient's quality of life. Kröner-Herwig et al. (2006) compared CBT with habituation-based (TRT-oriented) training, and found that these two methods are equally effective. In this study, a higher educational level of the patient favored the effect of habituation therapy, while comorbid psychiatric symptoms and diagnoses favored a beneficial effect of coping therapy.

Repetitive transcranial magnetic stimulation (rTMS) has been lately proposed as a treatment for tinnitus. This method is used to treat depression and chronic pain, and it is based on the effect of a magnetic field on the function of nerve cells in the cortical regions of the brain. Meng et al. (2011) made a Cochrane analysis on this topic and found that there is very limited support for the use of low-frequency rTMS for the treatment of patients with tinnitus. The studies are small, and differ from each other in terms of treatment protocols, outcome measures and follow-up. The quality of life improved in a single study with a low risk of bias based on a single outcome measure at a single point in time. The impact on tinnitus loudness was affected by pooling of the data, but the confidence interval was wide due to small sample size.

These studies suggest that rTMS is safe for tinnitus in the short-term, but that there was insufficient data to provide any support for the safety of this treatment in the long-term. The authors call for more prospective, randomized, placebo-controlled, double-blind studies with large sample sizes. There are 16 registered studies reported as being ongoing in the ClinicalTrials.gov-database, a database covering clinical trials (November 2012).

Hyperbaric oxygen treatment has been used to treat tinnitus, despite a fuzzy theoretical background and a lack of evidence of effect. Not maybe surprisingly, Bennett et al. (2007), who pooled the data of studies, reported that the control group was more likely to show improvement than the treatment group.

Several pharmacological therapies have been used to treat tinnitus. Vasodilators, corticosteroids, benzodiazepines, lidocaine and mexiletine have no proven efficacy. A Cochrane analysis on the efficacy of anticonvulsants in the treatment of tinnitus (Hoekstra et al. 2011) found seven studies that used gabapentin, carbamazepine, lamotrigine or flunarizine as a treatment. These studies had a significant risk for bias, and they failed to show any substantial positive effect on tinnitus, and smaller effects were doubtful. The widely used *Gingko biloba* extract does not have any beneficial effect (Rejali et al. 2004, Drew & Davies, 2001). There is a review with results favoring an effect of the extract (von Boetticher, 2011). The reliability of this review is, however, shadowed by the fact that it included a study with a drop-out rate of 63.3% (Morgenstern & Biermann, 2002). Be it relevant or not, it is also worth mentioning that most studies reviewed were published in less known journals in German and French.

Sullivan et al. (1993) reported that the tricyclic antidepressant nortriptyline has a significant effect on tinnitus when compared to placebo in tinnitus patients with major tinnitus or depressive symptoms. The tinnitus-related disability decreased, and even the tinnitus loudness was weaker on nortriptyline than placebo. The depression was relieved as measured with Hamilton Rating Scale for Depression. It is unclear if the effect of this medicine was direct toward the tinnitus or if the effect was secondary to improvement in the patient's degree of depression and sleep disturbances. Although the study plan was double-blind and placebo-controlled, the very common side effects of nortriptyline might have biased the blinding.

Robinson et al. (2005) found no significant effect of paroxetine on tinnitus in patients with tinnitus but without depression. Only the question ”How aggravated are you by your tinnitus?” showed significant improvement. Paroxetine is a selective serotonin re-uptake inhibitor and an antidepressant that is also used in panic disorder and obsessive-compulsive disorder. About one third of the patients had a history of depression, and only 10% had had an anxiety disorder or posttraumatic stress disorder. Beck Depression Inventory scores were mainly normal in this patient sample. However, the patients that took the maximum dose of 50 mg paroxetine daily improved significantly on the scales ”How severe is your tinnitus?”, ”How bothered are you by your tinnitus?”, and ” How aggravated are you by your tinnitus?”. There was even a 10 dB drop in tinnitus (measured with loudness matching) at least in one ear. It is important to notice that the patients in this study had significantly less depression and anxiety disorders than in other studies on psychiatric comorbidity with tinnitus.

The subjects with a tinnitus perception usually agree that the perception is reduced when they are in an environment with background noise. Hence, the use of enrichment of the sound environment, tinnitus maskers or hearing aids have been recommended to treat tinnitus, either as only treatment or in combination with other methods (e.g., TRT). Hobson et al. (2010) reviewed the literature on these methods, and found, again, low-quality studies with insufficient amounts of subjects. Most of these studies showed some improvement in the annoyance caused by tinnitus, but the loudness of the tinnitus did not change significantly. On the other hand, no adverse effects were reported, but could be argued that a tinnitus masker could remind the patient of the symptom and delay the habituation process. Hazell et al. (1985) found that hearing aids were as effective as tinnitus maskers and more regularly used. The patient with hearing impairment and tinnitus is likely to benefit from a hearing aid at least as regards improved hearing, and, hence, a hearing aid is a sensible choice for these subjects.

Acupuncture has no apparent effect on tinnitus (Park et al. 2000). Okamoto et al. (2010) has proposed that the neural plasticity of the auditory cortex could be stimulated by listening to music that has been filtered by exclusion of the tinnitus frequencies. There is only little evidence of an effect of this intriguing treatment.

There is no curative treatment for tinnitus. The best treatment so far seems to be enhancing habituation by counseling and enrichment of the sound environment. Treatment of depression, anxiety and sleep disturbances, if present, improves the quality of life of the patient, and probably improves the habituation process.

3. AIMS OF THE PRESENT STUDY

The elderly represent by far the greatest part of the subjects with hearing impairment. Life-time expectancy is increasing in Finland, and the demands on hearing rehabilitation are escalating. At the time this study was planned the resources for hearing aid fitting were generally inadequate in the whole of Finland; the queues for hearing aid fitting were long and there seemed to be serious process-related quality problems (e.g. poor hearing aid compliance). The impetus for this study was to evaluate the needs for hearing rehabilitation among the population in the age cohorts 70, 75, 80 and 85 years. This offered also a possibility to evaluate hearing-related problems in elderly, such as tinnitus and mental health. The specific aims of this study were:

1. to evaluate the reliability of the Finnish translation of HHIE-S as a tool for measuring the prevalence of hearing impairment in four elderly age cohorts,

2. to estimate the prevalence of hearing impairment in four elderly age cohorts,

3. to estimate the use and non-use of hearing aids in four elderly age cohorts, and report the reasons for poor hearing aid compliance, and

4. to analyze the association between tinnitus, depression and alexithymia in the elderly.

4. SUBJECTS, MATERIALS AND METHODS

4.1 Subjects and procedures

The study population consisted of home-dwelling elderly persons of four age cohorts living in Turku, an industrialized community of 175,000 inhabitants in southwestern Finland. The subjects were born in 1917, 1922, 1927 and 1932, and their respective ages were 70, 75, 80 and 85 years at the time of the study. Only Finnish-speaking subjects were included, and residents of hospitals and nursing homes were excluded. This sample and contact information was received from a database of Finnish Population Register Centre (Väestörekisterikeskus). Altogether 2717 subjects of the sample population of 4067 (66.7%) responded either to the mailed questionnaire [HHIE-S and single question (Appendix 1), and questions about hearing aid (Appendix 2)] or to a telephone interview in the summer of 2002. The subjects that responded to the questionnaire had a similar gender distribution as the same age cohorts in the population (64.4% and 65.5% were women, p= 0.33). The oldest age group responded less often than the younger ones (67.7%, 65.3%, 61.3% and 49.2% responded at the age of 70, 75, 80 and 85 years, p=0.002). (Fig.1)

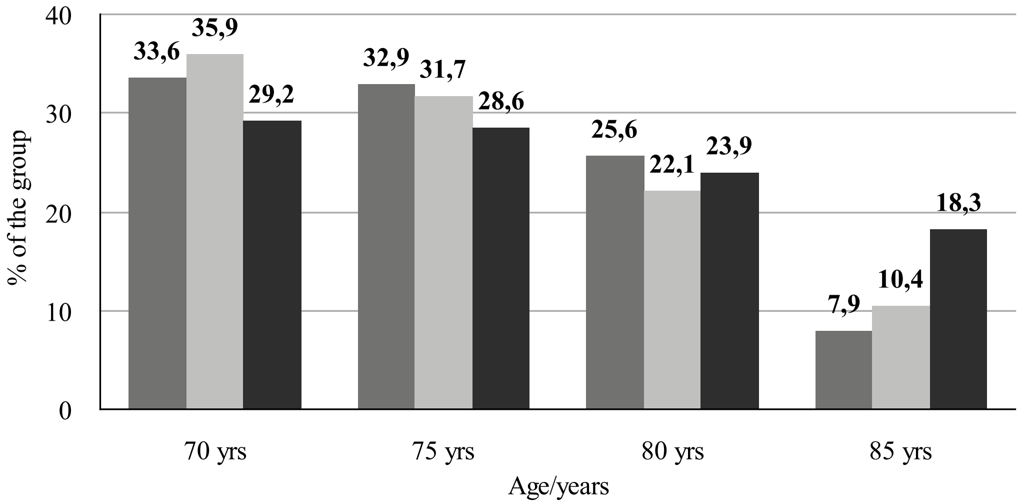

Figure 1. Age distribution (%) of the subjects attending for audiometry (N=164), subjects returning the hearing questionnaire (N=2717) and non-respondents (N=1350).

A subsample (a convenience sample) of 262 subjects was chosen by the initials of their family name (A or B) to attend for pure tone and speech audiometry for validating the questionnaire (HHIE-S) and a single hearing screening question. Altogether 230 people of this subsample responded either to the mailed hearing questionnaires or, if the subject did not respond, the questions were asked by a research assistant by telephone (response rate 87.7%). One hundred sixty-four subjects attended a hearing examination (62.6% of the sample). Of the invited to the hearing examination who did not attend, eleven had died, three had a severe illness that prevented examination, and 52 refused to attend for audiometry. Thirty-two people failed to respond or provide any information that could explain their non-responsiveness. The age and gender distribution did not differ between the subjects attending the hearing examination and the same general age cohorts of the population of Turku using χ^2-test (p=0.24 for age, and p=0.13 for gender).

The flow chart of the study is presented in Figure 2. Audiometric measurements were performed by a trained nurse between September 2002 and December 2003. Initially,

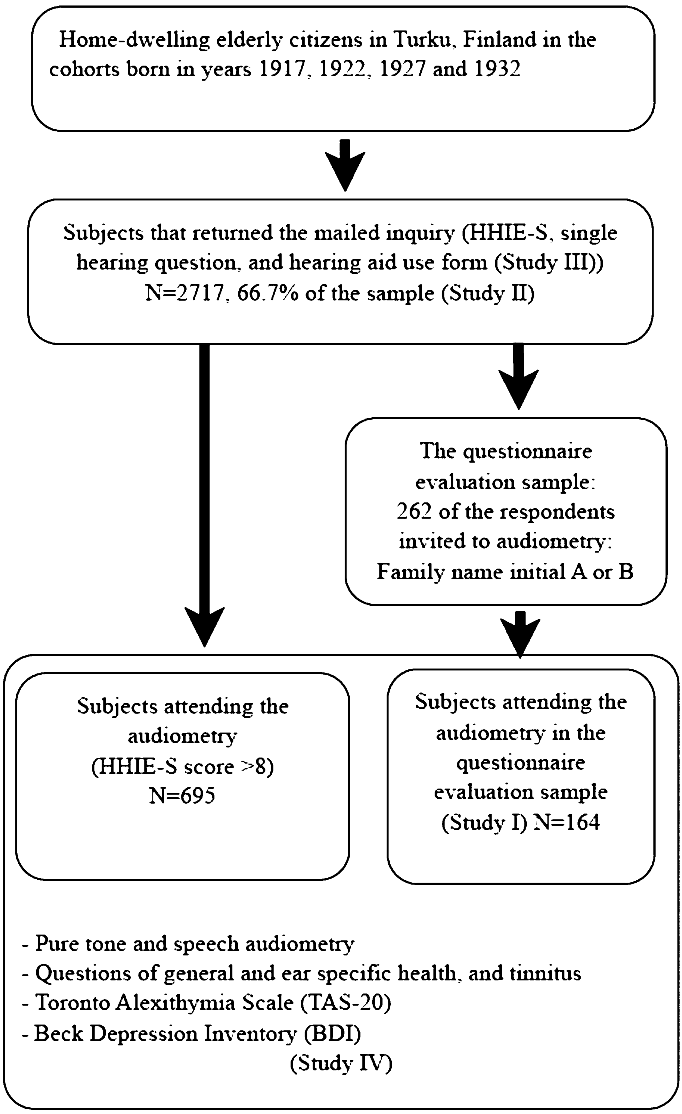

Figure 2. Flow chart of the study. (HHIE-S, Hearing Handicap Inventory for Elderly – Screening version)

the aim was to perform a hearing examination for all subjects who felt that their hearing was impaired (N=1098). The task proved to be beyond our resources, and could not be completed. Altogether 859 subjects (including 164 that were recruited for the validation of HHIE-S) attended for the hearing examination. Although the results of this sample could not be used to predict the prevalence of hearing impairment, the information obtained from these subjects was used to study the interaction of tinnitus, hearing impairment, and mental health factors. All 859 subjects that attended for audiometry were asked to respond to questions on their general and ear-specific health and tinnitus, and 583 subjects completed the Toronto Alexithymia Scale and Beck Depression Inventory.

4.2 Variables

4.2.1 Hearing Handicap Inventory for Elderly - Screening version (HHIE-S)

The HHIE-S questionnaire was translated into Finnish. The Finnish version was back-translated into English to exclude any significant errors in translation. The cultural differences between USA and Finland were presumed to be slight and no further changes were made. The HHIE-S score was calculated according to the original scale (never = 0, sometimes = 2, always = 4). The Finnish version of the HHIE-S is presented in Appendix 1.

4.2.2 "Do you feel you have a hearing loss?"

The same question as in BMHS ["Do you feel you have a hearing loss?" (Sindhusake et al., 2001)] was presented directly after the HHIE-S in the questionnaire. Response alternatives were "Yes" or "No".

4.2.3 The questions concerning the use of hearing aids

The questionnaire mailed to the target population included also a form with questions for hearing aid users (Appendix 2). The amount of hearing aid use was asked as a closed set questionnaire, and the alternatives were >6 and <6 hours a day, more than three days a week, seldom and never. The type of the hearing aid (behind the ear, in the ear or body-worn hearing aid), patient's experience in using it (time since first hearing aid fitting), the health care unit that had fitted the hearing aid, and the reasons for any lack of use were asked. The common problems of hearing aid use were presented as alternatives in a closed set of questions, and an open set question was presented for other reasons for minimal hearing aid use.

4.2.4 Toronto Alexithymia Scale (TAS-20)

TAS-20 was used to measure alexithymia, since it is the most widely used and carefully validated scale available for this purpose. Its internal consistency, test-retest reliability and convergent, discriminant and concurrent validity are good (Bagby et al. 1994a,b), and the psychometric properties of the Finnish version of TAS-20 is satisfactory (Joukamaa et al. 2001). TAS-20 measures the general dimension of alexithymia. The items are rated on a 5-point scale ranging from "strongly disagree" to "strongly agree". The TAS-20 scale consists of three subscales (TAS factors 1-3), which reflect the three main facets of the alexithymia concept: TAS factor 1 (=TASF1) assesses difficulties in identifying feelings (e.g. "I have feelings that I can't quite identify"), TAS factor 2 (=TASF2) concerns the difficulty in describing feelings (e.g. "It is difficult for me to find the right words for my feelings"), and TAS factor 3 (=TASF3) reflects concrete, externally oriented thinking (e.g. "I prefer talking to people about their daily activities rather than their feelings").

4.2.5 Beck Depression Inventory (BDI)

Depressiveness was measured with the abridged 13-item version of the original 21 item Beck Depression Inventory (Beck et al 1961). The Finnish version of this Inventory has good psychometric properties (Kaltiala-Heino et al. 1999).

4.2.6 Questions on tinnitus

The participants filled in a questionnaire on the presence or absence of tinnitus, degree of annoyance caused by tinnitus, audibility of tinnitus and nature of the sound they perceived (peeping, buzzing, humming or pulsating). The annoyance caused by tinnitus was classified into three groups: no tinnitus, tinnitus without annoyance and tinnitus with annoyance.

4.2.7 Audiometric measurements

The measurements were done in sound treated facilities using a Madsen Aurical audiometer (Madsen Electronics, Copenhagen, Denmark) and TDH-39 supra-aural earphones, in accordance with the standard ISO 8253-1 (International Organisation for Standardization, 1989), masking was used when indicated. The audiometer was calibrated according to ISO 389-1 (International Organisation for Standardization, 1998). The audiometric thresholds for air-conducted stimuli were established for the frequencies 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz in both ears. Bone-conduction hearing thresholds were measured at the frequencies 250, 500, 1000, 2000 and 4000 Hz, if the hearing threshold was worse than 15 dB at any frequency. Most of the subjects (N=744) completed also speech audiometry (International Organisation for Standardization, 1996). Speech reception thresholds (SRT) were measured with bisyllabic words. The speech discrimination was measured also with bisyllabic words: 25 words were presented at a level 30 dB higher than SRT, unless the maximum output level of 85 dB was reached. The ears of the subjects were examined by otomicroscopy, and the results were evaluated by an otolaryngologist who was a specialist in audiology (JS, SK, RJ).

4.3 Analysis

4.3.1 Relationship between self-reported hearing and measured hearing impairment in an elderly population in Finland

Pure tone averages (PTA) were calculated over the frequencies of 500, 1000, 2000 and 4000 Hz for the better (BEHL) and the worse ear. Sensitivity, specificity, and positive and negative predictive values were calculated for the HHIE-S values using 25, 35 and 40 dB $PTA_{0,5\text{-}4\ kHz}$ as cut-off points for hearing impairment for both the better and the worse ear. The positive predictive value is the probability of measured hearing impairment in a person with a HHIE-S score indicating a hearing impairment. The negative predictive value is the probability of normal hearing in a person with a HHIE-S score that indicates normal hearing. Twenty five and 40 dB were chosen as cut-off points for the limits of mild and moderate hearing impairment according to WHO Degrees of hearing impairment. Thirty-five dB $PTA_{0,5\text{-}4\ kHz}$ had been proposed as the minimum level for hearing aid fitting in public health services for the elderly in Finland, and that value was therefore included in this study. The receiver operating characteristic (ROC) curves were created for each of the three PTA levels by computing the sensitivity (true positive rate) and false positive rate of the test at each HHIE-S total score. AUC (area under curve) values were calculated for the ROC curves to describe the discriminatory power of the test at each level of hearing impairment. The single hearing question (*"Do you feel you have a hearing loss?"*) was also tested for sensitivity and specificity. The difference between the single hearing question and the HHIE-S score (≤ 8, >8) was analyzed with McNemar's test. Cohen's kappa coefficient was used to evaluate the agreement between the HHIE-S score (≤ 8, >8) and the single question. Differences in age, gender and hearing problems between the groups attending and refusing audiometry were tested using the χ^2-test. The statistical analyses were performed using the SAS version 8.2 software (SAS Institute Inc., NC, USA).

4.3.2 Prevalence of hearing problems in four urban elderly cohorts assessed by two self report methods

The total score of >8 was regarded as a sign of hearing impairment in HHIE-S, as was a positive answer to the single hearing question (*"Do you feel you have a hearing loss?"*). The differences of age and gender distribution between responders and non-responders were tested with the χ^2-test. Poisson's regression analysis was used to analyze the differences in the prevalences of hearing impairment between the age groups and gender. The results are presented as relative risks (RR) and 95% CL. The statistical analyses were performed using the SAS version 8.2 software (SAS Institute Inc., NC, USA).

4.3.3 Hearing aid compliance among elderly

The amount of hearing aid use and the age distribution of hearing aid use is presented, as well as the problems experienced in hearing aid use by frequent users and minimal users. The statistical analyses were performed using the SAS version 8.2 software (SAS Institute Inc., NC, USA). Statistical comparisons were done with the χ^2-test or Fisher's exact test. P-values less than 0.05 were considered statistically significant.

4.3.4 Alexithymia, depression and tinnitus in elderly people

Pure tone averages (PTA) were calculated over the frequencies of 500, 1000, 2000 and 4000 Hz and the subject's hearing was classified by the better ear as normal (PTA $\leq$ 30 dB HL) or as impaired (PTA >30 dB HL). The cut-off point of alexithymia recommended by the developers of the TAS-20 scale was used: subjects with TAS-20 total scores >60 were defined as alexithymic. Depressiveness was measured with the 13-item version of the Beck Depression Inventory. A score >8 was used as the cut-off point for depression. Social status was classified based on the previous occupation: high (entrepreneurs, white-collar workers), low (blue-collar workers), and other (unclassified, e.g. housewives or occupation not known). The data were analyzed using the SAS, Version 9.1. The χ^2-test was used for statistical analysis in group comparisons in the case of categorical variables, and analysis of variance in the case of continuous numerical variables. Multivariate logistic regression analysis was used to study the independent associations between the explanatory variables and the outcome. The variables included in the multivariate logistic regression analyses were tinnitus, impaired hearing, gender, age and social status. In the analyses concerning alexithymia depression was also included. Odds ratios (OR) and 95 % confidence limits (95% CL) were calculated.

4.4 Ethical considerations

The study was reviewed and approved by the Ethics Committee of the Hospital District of Southwest Finland, and the participants provided written informed consent for the study. The subjects were not given any financial compensation for participating.

5. RESULTS AND DISCUSSION

5.1 Relationship between self-reported hearing and measured hearing impairment in an elderly population in Finland (Study I)

This study was aimed to evaluate the usefulness of the HHIE-S questionnaire and a single hearing question in identifying subjects with and without hearing impairment. At least moderate hearing impairment (40 dB $BEHL_{0,5\text{-}4\ kHz}$) was detected reliably with both tools. The sensitivity was 100% and the specificity 59.7% for a HHIE-S score of >8. The corresponding rates were 100% and 70.7% for the single question. Increasing the cut-off level of the HHIE-S to >18 would reduce the specificity to 96% and increase the sensitivity to 81.3%. The ROC curves (Figure 3) for the different definitions of hearing impairment can be used to select an appropriate cut-off point for HHIE-S. If the BEHL of 25 dB is used as the limit of hearing impairment, the sensitivity of the HHIE-S score >8 drops to 80.8%, but the specificity is 79.1%. The single question was slightly less sensitive (76.1%) but more specific (89.5%) for mild or more severe hearing impairment. Mild hearing impairment is more difficult to identify with these methods. Confounding factors like differences in cognitive function of the subject, duration of hearing impairment, and social needs of a subject, may have relatively more effect on the degree of disability in a mild hearing impairment than more severe hearing impairment.

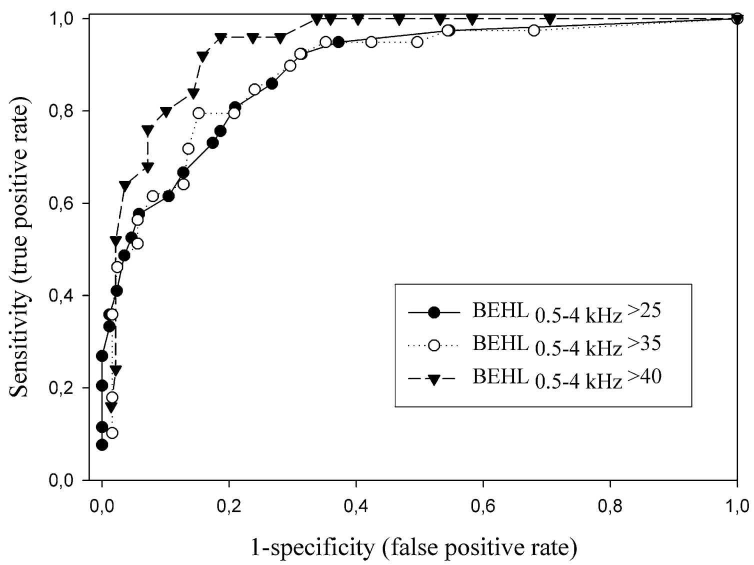

Figure 3. The ROC curves (sensitivity-false positive rate) for HHIE-S scores and three different limits of hearing impairment, score 0 on the left). (ROC, Receiver operating characteristic; BEHL, Better ear hearing level at frequencies 0.5, 1, 2 and 4 kHz; Score 34 missing, no observations)

The sensitivity and specificity of HHIE-S did not change significantly if hearing impairment was defined by the worse ear rather than the better ear. Asymmetric hearing impairment was, however, not rare. The percentage of subjects exceeding $PTA_{0.5\text{-}4\ kHz}$ limits of 25 and 40 dB was some 50 - 100% higher in almost every age group, if the worse ear was used instead of the better ear (Fig. 4).

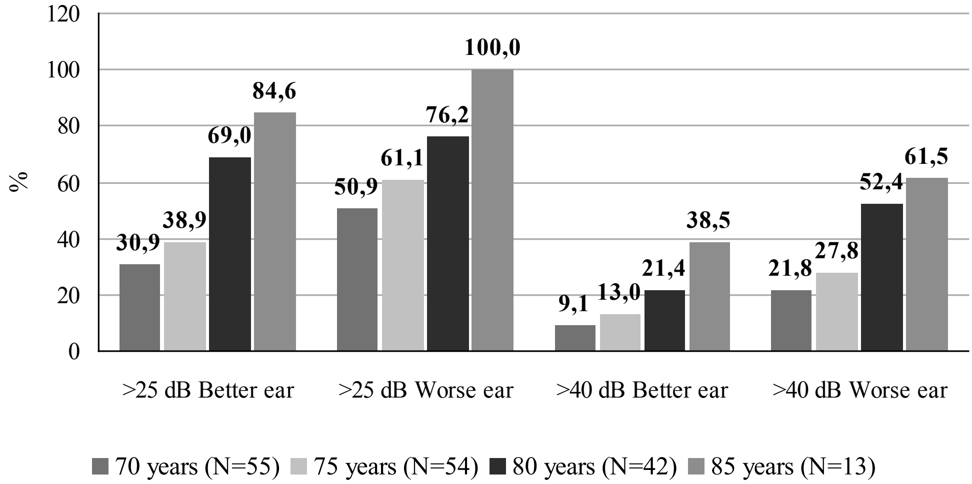

Figure 4. Proportion (%) of the subjects in age cohorts with a hearing impairment of at least 25 and 40 dB pure tone average at frequencies 0.5, 1, 2 and 4 kHz by the better and the worse ear in Study I (N=164).

The prevalence of hearing impairment by pure tone audiometry in this sample (N=164) was higher than expected in these age cohorts on the basis of previous studies (Rosenhall et al. 1989, Uimonen et al. 1999, Corna et al. 2009). The prevalence of subjects considering themselves to have impaired hearing as well as subjects exceeding the HHIE-S score 8 was higher among the attendants (40.1% and 49.4%, respectively) than non-attendants (33.3% and 43.4%, respectively). Selection bias is obviously possible - the subjects with no hearing disability attended the audiometry more reluctantly than the subjects with it. The nature of this sample, a convenience sample, based on the initials of the subjects' family name, instead of a random sample, is not likely to explain this phenomenon. The results of this study are similar to the results of previous studies using the original English version. In BMHS (Sindhusake et al. 2001) the sensitivity and specificity values were 58% and 85% for mild hearing impairment, and 80% and 76% for moderate hearing impairment, respectively. It seems that this Finnish version can be used to identify older adults with hearing impairment without further modifications. Slight differences in characteristics, especially specificity, depend probably on differences in the prevalence of hearing impairment between the populations studied.

Sporadic negative feedback was given by the subjects concerning the question of religious services (“Does a hearing problem cause you to attend religious services less often than you would like?”). This same question was extracted from the questionnaire, as the HHIE-S was modified to the screening version of HHIA to be used for subjects under 65 years by Newman et al. (1991).

The single question has certain advantages as a self-report measure of hearing. It is fast and easy to answer even if the subject has poor vision or some cognitive impairment. A lack of family members or a very loud TV set could affect the total score of HHIE-S, but this bias is less likely if a single question is used. The single question may have some advantages in a study where the needs for hearing rehabilitation are assessed. A person who feels that he/she has a hearing impairment would more likely be interested in rehabilitation (e.g., hearing aid fitting) than a person who does not experience hearing impairment, regardless of the hearing status. The latter person would probably lack the motivation necessary for rehabilitation (Gussekloo et al. 2003).

5.2 Prevalence of hearing problems in four urban elderly cohorts assessed by two self report methods (Study II)

The prevalence of hearing impairment was evaluated in four age cohorts in an urban community (Turku, Finland) using HHIE-S and a single question (*“Do you feel you have a hearing loss?”*). According to our previous study (Salonen et al. 2011) the cut-off score >18 of HHIE-S was very sensitive and reasonably specific to identify a hearing impairment of at least 40 dB $BEHL_{0,5\text{-}4\ kHz}$. The prevalence of HHIE-S score >18, indicating an at least moderate hearing impairment, was 21.1%, 25.6%, 28.8% and 38.9% in the age groups 70, 75, 80 and 85 years, respectively (Fig. 5). The HHIE-S cut off score of > 8 as an indicator of at least mild hearing impairment resulted in the corresponding prevalence values 37.7%, 42.4%, 47.2% and 54.1%. The subjects felt they had hearing impairment in 25.5%, 32.7%, 38.7% and 46.2%, respectively (Fig. 6). The hearing impairment is more common in men with all three methods in all cohorts, but in the cohort of persons aged 85 years the difference is minimal, as hearing impairment is more of a rule than an exception.

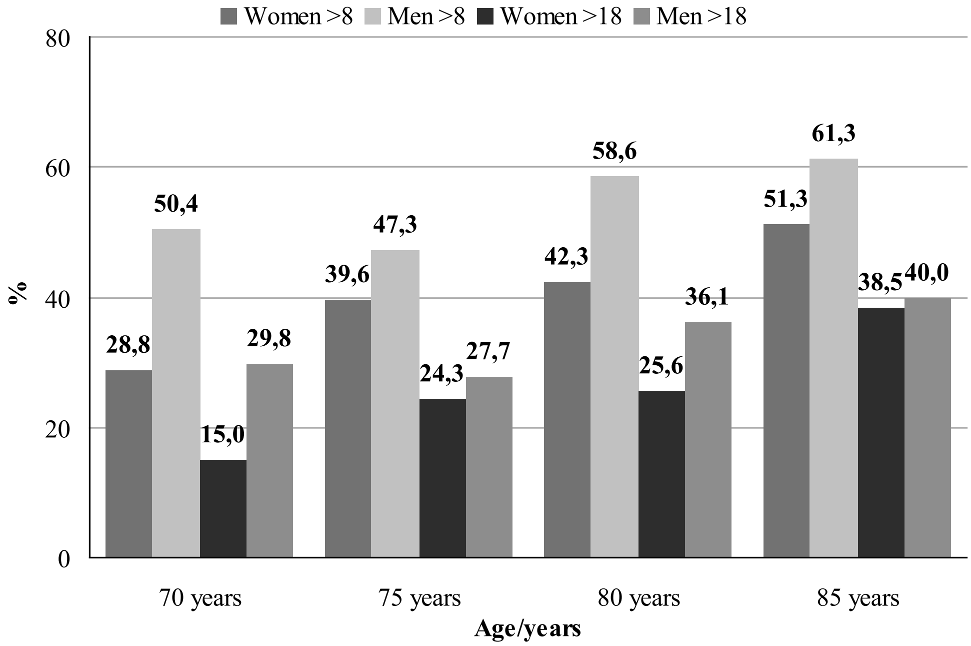

Figure 5. Prevalence (%) of HHIE-S >8 and >18 among four age cohorts in Turku, Finland, by women (N=1751) and men (N=965) (HHIE-S, Hearing Handicap Inventory for Elderly-Screening version)

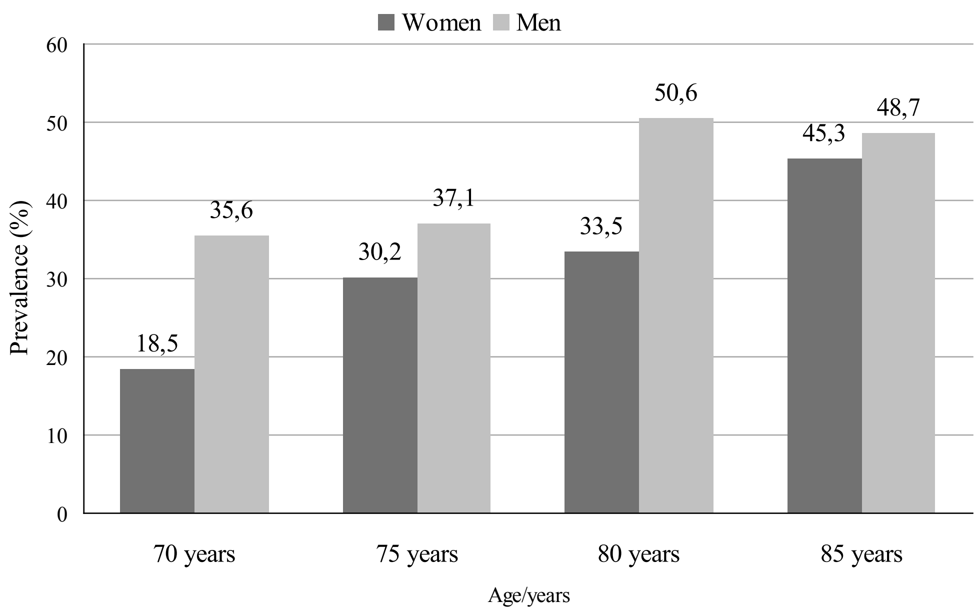

Figure 6. Prevalence (%) of hearing impairment by the single question ” *Do you feel you have a hearing loss?*” among four age cohorts in Turku, Finland, by women and men (N=2717).

The sample was 2717 subjects which is considerably large, although the response rate was only 66.7%. The results at least in the age group of 75 years are identical to a previous study by Uimonen et al. (1997). The oldest age group responded significantly more reluctantly than the younger ones. The decline in intellectual capabilities and functional resources with advancing age could explain this. Although this population was living at home (without or with help from social authorities or family), there is a marked part of population that is not capable of filling in a questionnaire. A study based on direct interview would avoid this bias. It is possible that subjects with hearing impairment were more eager to take part in this study, but there is no evidence to support this assumption. A study on the prevalence of hearing impairment would ideally be based on measured hearing impairment. It was originally our intention, but it would have required a different approach and a different study design. The results of studies that report a higher degree of cognitive impairment among subjects with hearing impairment (Cacciatore et al. 1999, Lin et al. 2011a) suggest that hearing impairment could be more common among patients of nursing homes and hospitals. This could also cause an overrepresentation of these subjects among non-respondents of this study. These are hypotheses that remain unanswered in our study, and demand further research.

5.3 Hearing aid compliance among elderly (Study III)

This study was based on a mailed inquiry and the target population was 4067 subjects. Altogether, 249 hearing aid users responded, which is 9.2% of the population. The exact amount of hearing aid users is unknown, but in Kuopio, Finland, there was a prevalence of hearing aid users of 16.6% among subjects at 75 years of age (Lupsakko et al. 2005). Of the respondents, 56,2% used the hearing aid daily, and 27.7% more than six hours a day. The proportion of subjects that never used their hearing aid was 10.8% (Fig. 7). The use of hearing aids had a tendency to decline with advancing age, as reported in previous studies by Surr et al. (1978), Sorri et al. (1984) and Vuorialho et al. (2006). The

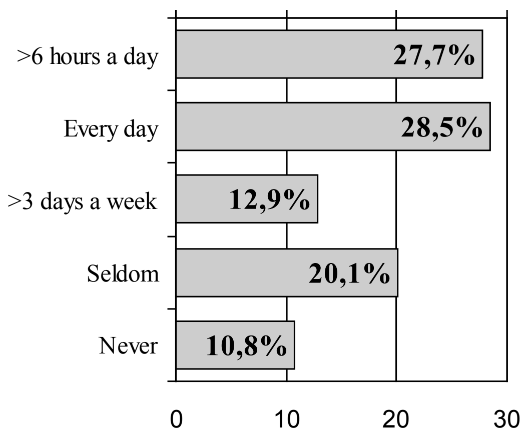

Figure 7. Distribution (%) of hearing aid use in an elderly sample of hearing aid owners in Turku, Finland (N=249).

most common reasons for minimal use were the disturbing background noises, acoustic feedback problems, battery costs, and poor motivation for hearing aid use. The problems in hearing aid use among frequent users and minimal or non-users are presented in Fig.8.

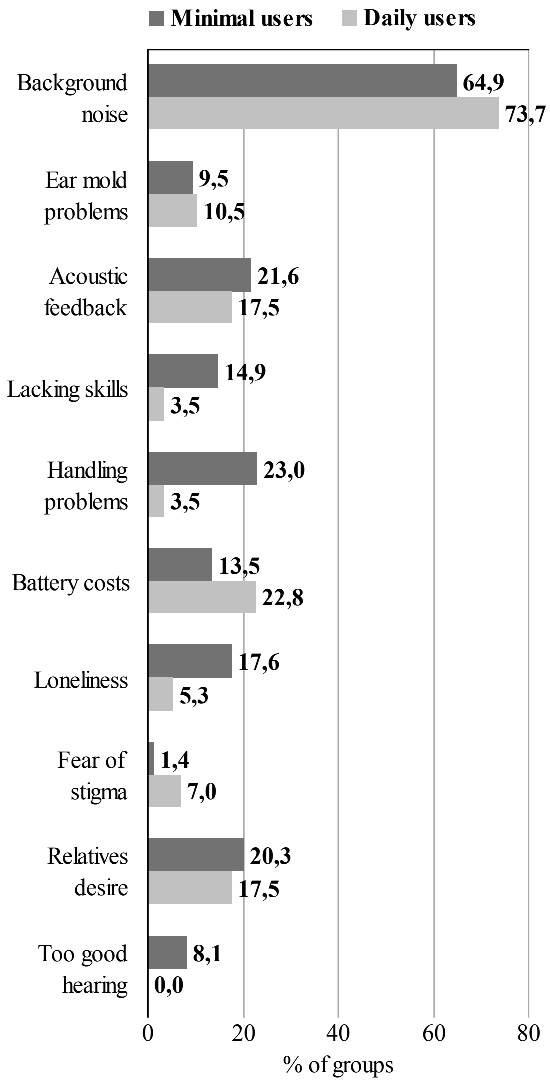

Figure 8. Problems experienced by elderly hearing aid users in Finland among subjects using hearing aids seldom or never (Minimal users, N=74) and every day (Daily users, N=57) (% in group, respectively).

The use of hearing aids has improved over the years, as has also been reported by Vuorialho et al. (2006), but there is still a significant amount of hearing aids in minimal use. The advances in hearing aid technology are likely to enhance use of hearing aids further. Adaptive directional microphones, noise reduction and speech detection techniques all improve the listening satisfaction. This may reduce the initial annoyance as a new hearing aid user starts to accommodate to new hearing experiences, and hence improve hearing aid compliance. The disturbing noise and feedback problems were equally often reported as being disturbing by those who wore and those who did not wear their hearing aids daily. The problems that were significantly more common in the low compliance group were problems in handling and positioning the hearing aid in the ear, lack of social contacts, and a lack of the subjective need for a hearing aid ("too good hearing"). Therefore, probably one of the most effective ways to improve the efficacy of hearing aid fitting process would be to enhance communication with the patient before referral for hearing aid fitting, during the fitting procedure and during counseling.

The main weakness in this study is that it does not represent the technical situation of today. At the time of this study the majority of hearing aids used analog signal processing, and the ones that used digital processing were very simple compared to modern hearing aids. However, a fifth of the poor compliance group had problems positioning the hearing aid in the ear, and a fifth complained that relatives forced the patient to get a hearing aid. Loneliness was a reason for minimal use in 17.6% of the subjects. These factors will probably not change with technical advances, and need to be taken into account when hearing rehabilitation is planned. The other main weakness is a lack of data on the prevalence of hearing aid users. There is, consequently, some uncertainty as to how well this sample represents the whole group of hearing aid users.

5.4 Alexithymia, depression and tinnitus in elderly people (Study IV)

The hypothesis underlying this study was that tinnitus has some common aspects with somatization disorders and that somatization is associated with alexithymia. Subjects who experience much annoyance from tinnitus would consequently be alexithymic. The study sample consisted of 583 people who attended a hearing examination. The Toronto Alexithymia Scale (TAS-20) was used as the measure of alexithymia, depressiveness was measured with the 13-item version of the Beck Depression Inventory, and the subjective experience of tinnitus was assessed with a questionnaire. A high BDI score (>8) was associated with harmful tinnitus among women in the pairwise analysis, but this association disappeared in the multivariate analysis (Table 4). There was no difference between tinnitus annoyance and depressiveness among men. This finding is in conflict with several previous studies (Folmer et al. 1999, Gopinath et al. 2010, Krog et al. 2010) which have reported that an association between tinnitus annoyance and depression exists.

Contrary to the hypothesis, the TAS-20 score did not correlate with the severity of tinnitus. In fact, the highest TAS scores were encountered among subjects who had tinnitus but who did not find it subjectively annoying (Table 5). There was no significant association between high TAS scores and hearing impairment.

In this population sample the prevalence of hearing impairment, and, hence, of tinnitus was high. About one third of subjects had tinnitus with annoyance, about one third without annoyance, and one third did not have tinnitus. The severity of annoying tinnitus is not easy to classify, and the classification of annoyance in our study might have been too insensitive, which might explain the lack of association between alexithymia and annoying tinnitus. Most clinical patients with initially disabling tinnitus do seem to benefit from simple counseling and sound enrichment, and only a minority do not get adequately habituated to their tinnitus (Bauer & Brozoski, 2011). The latter group may actually be the one with increased risk of somatization and alexithymia. This study did not differentiate between these two groups, because of the epidemiological design of the study. There seems to be a generation-related difference in reporting of tinnitus (Nondahl et al. 2012). The elderly might not represent the typical tinnitus patients, as there are several disabilities and sufferings in their lives in any case, and the perception of tinnitus is very common among the elderly. Further clinical studies are needed with patients seeking help for their tinnitus.

Table 4. Association between depressiveness (BDI >8) and tinnitus among elderly people. BDI, Beck Depression Inventory, NS Non-significant (>0.05) *Crude*, according to pairwise general linear model analysis. *Adjusted*, according to general linear model analysis in which tinnitus, impaired hearing, sex, age and social situation were included.

Group (P, Crude/Adjusted)	All (NS/NS)	Women (.021/NS)	Men (NS/NS)
Annoying tinnitus	20.3	24.4	15.2
Non-annoying tinnitus	17.8	20.0	15.1
No tinnitus	11.6	10.5	13.5

Table 5. Association between tinnitus and alexithymia (TAS-20 score >60) among elderly people. TAS-20, Toronto Alexithymia Scale, SD Standard deviation, NS Non-significant (>0.05) *Crude*, according to pairwise general linear model analysis. *Adjusted*, according to general linear model analysis in which tinnitus, impaired hearing, sex, age, social situation and depression were included.

	Prevalence of alexithymia (%)			Mean of TAS-20 total score (SD)		
Group (P, Crude/Adjusted)	All (.005/.04)	Women (.029/NS)	Men (NS/NS)	All (.002/.01)	Women (.03/NS)	Men (NS/.046)
Annoying tinnitus	23.3	24.7	21.6	52.1 (11.6)	51.9 (12.3)	52.4 (10.7)
Non-annoying tinnitus	27.8	24.5	32.1	53.6 (10.8)	52.5 (10.5)	55.1 (10.9)
No tinnitus	14.9	13.0	18.3	49.9 (10.3)	49.0 (10.8)	51.4 (9.2)

5.5 General discussion

Life expectancy is increasing constantly in the developed countries. Currently, a Finnish woman can expect to live 22 years and a Finnish man 17 years after her/his 65th birthday (Statistics Finland, 2011). The estimated rise in Finnish citizens 65 years or older during the next 40 years is 78% (Statistics Finland, 2009, Table 6).

The prevalence of hearing impairment was in the present study 21-38% among persons aged 70 years and over 40% among persons aged 85 years. Similar findings have been reported previously (Uimonen et al. 1999, Pedersen et al. 1989, Hietanen et al. 2005, Corna et al. 2009). Clearly, hearing impairment could be regarded as a normal phenomenon in elderly. Sorri et al. (2001) estimated that the number of hearing aids provided annually in Finland is 14,000, and about 20% of hearing aid fittings are binaural. If one makes the conservative assumption that the prevalence of hearing impairment requiring hearing aid rehabilitation is 20% in the Finnish population aged 65 years and older, there would be 188,000 elderly hearing aid users. The estimated technical life span of a hearing aid is 5 years, which yields an annual need of 37,600 (monaural or binaural) hearing aid fittings. Over the next ten years this population will grow by 37%.

Table 6. Expected number and share of citizens aged >64 years in Finland (Statistics Finland, 2009)

Year	N	% of the population
2000	777,198	15.0
2010	943,985	17.6
2020	1,290,143	22.9
2030	1,525,155	26.1
2040	1,607,768	26.9
2050	1,680,637	27.6

A decline in the relative prevalence of hearing impairment is also possible. The veterans of the second World War are all over 85. Noise-induced hearing impairment among them is common. Proper hearing protection in the industry became widely used during the 1970's. Hearing protection during recreational activities like shooting and hunting is also increasing. All these changes will probably reduce the effect of noise-induced hearing impairment among elderly. On the other hand, leisure-time noise exposure, especially music, is still common among adults (Jokitulppo et al. 2006). The advances in preventing and treating vascular risk factors and diabetes, as well as combating smoking, may all affect the future prevalence of age-related hearing impairment. Still, it is important to note that the prevalence of diabetes is increasing (Hu et al. 2008), and this might affect also the occurrence of hearing impairment.

With the advances of hearing aid technology compliance with using the aids is increasing (Vuorialho et al. 2006). These advances affect especially the aspects that were most disturbing to frequent hearing aid users, and they also reduce the initial annoyance experienced by hearing aid novices. Better training and education will also improve hearing aid use. Projects that aim to spread a positive image of hearing aid use and, probably, modern design of the hearing aids could further improve compliance. All these means are worthwhile, because 10-30% of the hearing aids fitted annually are actually not used, and this is equivalent with a loss of 2-6 million Euros every year in Finland (500 Euros/hearing aid).

The increase in the hearing-impaired population and the needs for hearing aid rehabilitation call for streamlining of the hearing aid fitting process. Audiometry itself has changed surprisingly little despite the advances in computer technology, and automated procedures of tone or speech audiometry are not used clinically. The hearing aid fitting programs are continuously evolving, but the ultimate effect of this on the consumption of time in the fitting process is minimal. The most time consuming part of this process is counseling and training of the patient. Although the savings obtained by cutting the counseling could lead to quality problems in the fitting process, converting follow-up visits to group training visits may lead to equally good results as individual visits and lead to cost savings (Collins et al. 2007). The emergence of real ear measurement methods that use the speech signal to evaluate the frequency response of a hearing aid in the ear may improve the quality of hearing aid fitting, and diminish the need for repeated tuning sessions. This is at the moment purely speculative since there is a lack of studies on this topic.

The initial reason for this study was to gather information about the prevalence of hearing impairment in the elderly to estimate the number of those needing hearing rehabilitation. In 2002 the annual hearing aid fitting rate was approximately 800 fittings yearly, the waiting time was over two years, and there was substantial mortality while waiting for rehabilitation. The interpolated prevalence among elderly aged more than 70 years ranges from 5100 to 6800 (by single question and HHIE-S >8, respectively) which would equal an annual need of about 1000-1300 hearing aid fittings. The increase in human and material resources, and enhancement of the rehabilitation pathways have improved the situation so that the need for hearing aid rehabilitation is currently met at an annual rate of about 1 000 patients. This development supports the results of this study and the demographics in our region predicts that development will continue and the need for audiological services will increase.

6. SUMMARY

Age-related hearing impairment is one of the most common disabilities of elderly people, and its health-economic significance is growing, as life expectancy in the developed countries is increasing. The effects of impaired hearing on communication and social life are clear, but there is some evidence that hearing impairment is associated with depression, cognitive impairment and dementia. Despite the impact of age-related hearing impairment on personal and societal life, there is only little knowledge of the prevalence of hearing impairment in the elderly.

The primary aim of this study was to investigate the prevalence of hearing impairment in four elderly age cohorts (70, 75, 80 and 85 years). For this, the HHIE-S needed to be translated into Finnish and evaluated as a tool for measuring the prevalence of hearing impairment in elderly. Furthermore, the effectiveness of hearing aid rehabilitation in this population sample was evaluated by enquiry that covered the amount of hearing aid use and non-use, and the reasons for poor compliance. The associations between tinnitus, depression and alexithymia were studied in a sample of subjects who attended for hearing examinations.

A questionnaire, including HHIE-S, single hearing question and questions concerning hearing aid use, was sent to four home-dwelling age cohorts in Turku, Finland (N=4067). The response rate was 66.7%. A subsample of the respondents (N=230) was invited for hearing examinations to evaluate the reliability of HHIE-S, but only 164 subjects attended. Altogether 859 subjects were examined using pure tone and speech audiometry and they were asked to respond to questions on general and ear specific health and tinnitus, and they completed the Toronto Alexithymia Scale and Beck Depression Inventory questionnaires to provide information on the interaction between tinnitus, hearing impairment, and mental health.

The prevalence of hearing impairment in elderly is high, and strongly age dependent. A HHIE-S score of >8 was obtained in 37.7%, 42.4%, 47.2% and 54.1% for the age groups, respectively, indicating at least mild hearing impairment. A HHIE-S score of >18 (at least moderate hearing impairment) was found in 21.1%, 25.6%, 28.8% and 38.9% of the respondents, respectively. The single question *"Do you feel you have a hearing loss?"* was put to the respondents of whom 25.5%, 32.7%, 38.7% and 46.2%, respectively, answered "yes". These results show that over one fourth of the subjects in their 70's and almost half of the subjects in their 80's need hearing rehabilitation.

The Finnish version of the HHIE-S is relatively sensitive and specific, and thus it can be used as a tool for epidemiological studies and for screening in clinical practice. The use of different cut-off limits to evaluate the prevalence of at least mild (>8) or at least moderate (>18) hearing impairment gives more value to this inventory. However, the single hearing question *"Do you feel you have a hearing loss?"* has also some advantages. It is very simple and easily understood, it is very sensitive to identify a hearing impairment of >40 dB $BEHL_{0,5\text{-}4\ kHz}$, and it is sensitive for identifying mild hearing impairment. Unfortunately, neither of these methods can replace pure tone audiometry.

The use of hearing aids is far from optimal. As many as 30.9% of hearing aid owners use their hearing aids seldom or never. In the sample of 249 patients, only 56.2% used their hearing aids daily. Hearing aid compliance has a tendency to decline with advancing age. Problems with handling the aid, problems with inserting the aid in the ear, lack of social contacts, and lack of the subjective need for a hearing aid ("too good hearing") were the difficulties of hearing aid use that were significantly more common in the low-compliance group compared to the group where compliance was good. Probably one of the most effective ways to improve the efficacy of hearing aid fitting process would be to inform the patient better before referral for hearing aid fitting, during fitting and during counseling visits and telephone contacts.

Tinnitus is a common symptom of hearing impairment, and very common among the elderly. The annoyance caused by tinnitus is not associated with the degree of hearing impairment, and the factors affecting annoyance are poorly known. Although the annoyance caused by tinnitus is associated with somatoform disorders, and although alexithymia is common among somatizing patients, we could not confirm an association between the severity of tinnitus and the TAS-20 score, which measures alexithymia. This association needs, however, further study involving patients who seek help for their tinnitus, rather than subjects in an epidemiological study like the present one.

7. CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn.

1. The Finnish version of Hearing Handicap Inventory for Elderly - Screening version (HHIE-S) was introduced. It is sensitive and specific for detecting hearing impairment of >40 dB $BEHL_{0,5\text{-}4\ kHz}$. The specificity of the HHIE-S is improved, while still retaining the sensitivity, if the cut-off score is raised from the standard >8 to no less than >18. The sensitivity and specificity are both about 80% if 25 dB $BEHL_{0,5\text{-}4\ kHz}$ is used as a limit for hearing impairment, and >8 is used as a cut-off score.

2. A single question *"Do you feel you have a hearing loss?"* was very sensitive (100%), and quite specific (70.7%) for identifying moderate or worse hearing impairment. It is more specific than the HHIE-S at a cut-off score >8 for identifying hearing impairment of at least 25 dB $BEHL_{0,5\text{-}4\ kHz}$.

3. Hearing impairment is very common among elderly people. The prevalence of moderate or more severe hearing impairment increases from 21% in the group of people aged 70 years to 39% in the group aged 85 years. Mild or worse hearing impairment is present in 26-38% of those aged 70 years and in 46-54% of those aged 85 years.

4. No less than 30.9% of hearing aid owners use their hearing aid seldom or never. Some of the common problems associated with handling and using hearing aids will be overcome by technological advances, but there is a need for more counseling and better patient selection.

5. Tinnitus is common among elderly people with hearing impairment. Depressiveness is probably associated with annoying tinnitus, but there was no association between annoying tinnitus and alexithymia measured with Toronto Alexithymia Scale.

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APPENDIX 1.

Kuulonlaskun haitan arviointilomake (HHIE-S)

Nimi: ________________________________ Syntymäaika: ____________________

Vastauspäivämäärä: ________________

Kaavakkeessa olevilla kysymyksillä tiedustellaan onko Teillä kuulovaikeuksia erilaisissa keskustelu- ja kuuntelutilanteissa. Vastausten avulla voidaan arvioida mahdollisen kuulonlaskun vaikeusastetta ja suunnitella korjaustoimenpiteitä.
Vastatkaa **KYLLÄ, JOSKUS** tai **EI** jokaiseen kysymykseen. Älkää jättäkö vastaamatta kysymykseen vaikka välttäisittekin kyseistä tilannetta kuulo-ongelmien vuoksi. Jos käytätte kuulokojetta, vastatkaa sen mukaisesti, miten selviätte **ilman** kuulokojetta.

E-1. Kiusaannutteko kuulovaikeuksien vuoksi tavatessanne uusia ihmisiä? .... ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

E-2. Turhaudutteko kuulovaikeuksien vuoksi keskustellessanne perheenjäsentenne kanssa?.................. ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

S-3. Onko Teillä vaikeuksia kuulla kuiskausta?........... ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

E-4. Koetteko itsenne kuulovammaiseksi?.... .... ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

S-5. Aiheuttaako kuulonne vaikeuksia vieraillessanne ystävien, sukulaisten tai naapureiden luona?......... ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

S-6. Käyttekö kuulovaikeuksien vuoksi uskonnollisissa tilaisuuksissa harvemmin kuin haluaisitte?.......... ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

E-7. Aiheuttavatko kuulovaikeutenne kiistaa perheenjäsentenne kanssa?...................................... ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

S-8. Aiheuttaako kuulonne vaikeuksia television tai radion kuuntelussa?................................... ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

E-9. Haittaako tai rajoittaako kuulonne henkilökohtaista tai sosiaalista elämäänne?............................. ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

S-10. Aiheuttaako kuulonne vaikeuksia ollessanne ravintolassa ystävien tai sukulaisten kanssa?........ ☐ **KYLLÄ** ☐ **JOSKUS** ☐ **EI**

Koetteko itsenne huonokuuloiseksi? ☐ **KYLLÄ** ☐ **EI**

APPENDIX 2.

Jos Teillä on kuulokoje, vastatkaa myös näihin kysymyksiin:

Nimi:________________________________

Onko Teillä kuulokoje ❒ toisessa korvassa ❒ molemmissa korvissa?

Onko Teillä aikaisemmin ollut kuulokojeita? ❒ Yksi ❒ Kaksi ❒ Kolme ❒____

Kuinka kauan Teillä on ollut kuulokoje? _____________ vuotta

Onko kuulokojeenne ❒ Korvantauskoje ❒ Korvakäytäväkoje
❒ Taskukoje

Mistä olette kojeenne saanut?____

Käytättekö kuulokojetta?
❒ Joka päivä yli 6 tuntia
❒ Päivittäin
❒ Yli kolmena päivänä viikossa
❒ Harvoin
❒ En lainkaan

Merkitkää kuulokojeen käyttöä haittaavia syitä.
(Valitkaa yksi tai useampi vaihtoehto)

❒ Taustamelu häiritsee
❒ Korvakappale painaa
❒ Koje vinkuu
❒ En osaa käyttää kojetta
❒ En saa kojetta korvaan
❒ Paristot ovat kalliita
❒ Olen niin yksinäinen, etten tarvitse kojetta
❒ Muut ihmiset huomaavat kojeen
❒ Koje hankittiin, koska omaiset halusivat niin
❒ Kuuloni on niin hyvä, etten tarvitse kojetta
❒ Muu syy, mikä? ____