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On noise and hearing loss

Prevalence and reference data

Magnus Johansson

LINKÖPINGS UNIVERSITET

Department of Neuroscience and Locomotion
Division of Technical Audiology
Linköping University, SE-581 83 Linköping, Sweden

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Cover photo:
Water turbine 'cochlea' under construction at the engineering workshop company Nyqvist & Holm AB in Trollhättan, Sweden.

ON NOISE AND HEARING LOSS

PREVALENCE AND REFERENCE DATA

Technical Audiology
Faculty of Health Sciences
Linköping University
SE-581 85 Linköping

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To Lisa

Abstract

Noise exposure is one of the most prevalent causes of irreversible occupational disease in Sweden and in many other countries. In hearing conservation programs, aimed at preventing noise-induced hearing loss, audiometry is an important instrument to highlight the risks and to assess the effectiveness of the program. A hazardous working environment and persons affected by it can be identified by monitoring the hearing thresholds of individual employees or groups of employees over time. However, in order to evaluate the prevalence of occupational noise-induced hearing loss, relevant reference data of unexposed subjects is needed.

The first part of this dissertation concerns the changes in hearing thresholds over three decades in two occupational environments with high noise levels in the province of Östergötland, Sweden: the mechanical and the wood processing industries. The results show a positive trend, with improving median hearing thresholds from the 1970s into the 1990s. However, the hearing loss present also in the best period, during the 1990s, was probably greater than if the occupational noise exposure had not occurred. This study made clear the need for a valid reference data base, representing the statistical distribution of hearing threshold levels in a population not exposed to occupational noise but otherwise comparable to the group under study.

In the second part of the dissertation, reference data for hearing threshold levels in women and men aged from 20 to 79 years are presented, based on measurements of 603 randomly selected individuals in Östergötland. A mathematical model is introduced, based on the hyperbolic tangent function, describing the hearing threshold levels as functions of age. The results show an age-related gender difference, with poorer hearing for men in age groups above 50 years.

The prevalence of different degree of hearing loss and tinnitus is described for the same population in the third part of the dissertation. The overall prevalence of mild, moderate, severe or profound hearing loss was 20.9% collectively for women and 25.0% collectively for men. Tinnitus was reported by 8.9% of the women and 17.6% of the men. Approximately 2.4% of the subjects under study had been provided with hearing aids. However, about 7.7% were estimated to potentially benefit from hearing aids as estimated from their degree of hearing loss.

Noise-induced hearing loss primarily causes damage to the outer hair cells of the inner ear. The fourth and last part of the dissertation evaluates the outer hair cell function, using otoacoustic emission measurements (OAE). Prevalence results from three different measuring techniques are presented: spontaneous otoacoustic emissions (SOAE), transient evoked otoacoustic emissions (TEOAE) and distortion product otoacoustic emissions (DPOAE). Gender and age effects on the recorded emission levels were also investigated. Women showed higher emission levels compared to men and for both women and men the emission levels decreased with increasing age. The results from the OAE recordings were shown to be somewhat affected by the state of the middle ear. The study included tympanometry, and the relation of the outcome of

this test to the otoacoustic emissions is described, where high middle ear compliance resulted in low emission level. Reference data for the tympanometric measurements are also presented.

The results of this project form an essential part of the important work against noise-induced hearing loss, which needs continuous monitoring. The reference data presented here will provide a valid and reliable data base for the future assessment of hearing tests performed by occupational health centres in Sweden. This data base will in turn prove useful for comparison studies for Sweden as a responsible fellow EU member country setting high standards for work force safety. The statistical distribution of hearing threshold levels as a function of age for men and women in tabulated form is available on the Swedish Work Environment Authority (Arbetsmiljöverket) web site: http://www.av.se/publikationer/bocker/fysiskt/h293.shtm

Preface

This dissertation comprises a short introduction to the auditory system, to noise-induced hearing loss and to measurement techniques for hearing loss evaluation. It contains the results and conclusions from the following papers, which are referred to as *Paper A, B, C* and *D* in the text.

A. Johansson M, Arlinger S (2001). The development of noise-induced hearing loss in the Swedish County of Östergötland in the 1980s and the 1990s. Noise & Health 3:15–28.

B. Johansson M, Arlinger S (2002). Hearing threshold levels for an otologically unscreened, non-occupationally noise-exposed population in Sweden. Int J Audiol 41:180–194.

C. Johansson M, Arlinger S (2003). Prevalence of hearing impairment in a population in Sweden. Int J Audiol, 42:18–28. Including erratum of table 3, which will be published in Int J Audiol, 42(2).

D. Johansson M, Arlinger S (2003). Otoacoustic emissions and tympanometry in a general adult population in Sweden. Int J Audiol, *in press*.

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Magnus Johansson

Linköping, January 2003

Contents

Papers

A. Johansson M, Arlinger S (2001). The development of noise-induced hearing loss in the Swedish County of Östergötland in the 1980s and the 1990s. Noise & Health 3:15–28.

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Notation

Abbreviations and acronyms used in the dissertation:

ANOVA	Analysis of Variance
BE	Better Ear
daPa	dekaPascal
DPOAE	Distortion Product Otoacoustic Emission
f	frequency
HL	Hearing Level
HTL	Hearing Threshold Level
M3	Pure-tone average of HTL at 0.5, 1 and 2 kHz
M4	Pure-tone average of HTL at 0.5, 1, 2 and 4 kHz
M5	Pure-tone average of HTL at 0.5, 1, 2, 3 and 4 kHz
MANCOVA	Multivariate Analysis of Covariance
MANOVA	Multivariate Analysis of Variance
OAE	Otoacoustic Emission
r^2	Correlation Coefficient
SOAE	Spontaneous Otoacoustic Emission
SPL	Sound Pressure Level
TEOAE	Transient Evoked Otoacoustic Emission
TTS	Temporary Threshold Shift
WE	Worse Ear

Chapter 1

Introduction

"This evolution of music is comparable to the multiplication of machines, which everywhere collaborate with man. Not only in the noisy atmosphere of the great cities, but even in the country, which until yesterday was normally silent. Today, the machine has created such a variety and contention of noises that pure sound in its slightness and monotony no longer provokes emotion."

-Luigi Russolo, Milan, March 11th 1913

The modern society has brought positive and some less positive changes to men. The industrial revolution has introduced new environments and new sources of sounds affecting the human being. The vulnerability of our auditory system has become evident.

Occupational noise exposure represents a substantial source for hearing loss. In Sweden and in many other countries noise is one of the most prevalent causes of irreversible occupational disease. To prevent hearing loss, hearing conservation programs have been introduced, where hearing investigations are a crucial constituent. Both continuous monitoring and comparisons to valid reference data form essential parts of the important work against noise-induced hearing loss.

The following chapters comprise a short overview of the human auditory system and how the auditory function is affected by ageing and hazardous noise exposure. Methods for determination of noise-induced hearing loss are presented. Effects from excessive noise exposure are described and some noise-exposed groups in the society are highlighted.

On this basis and previously published results, the objectives and results from four studies conducted on occupationally noise-exposed and not exposed populations are presented and discussed in the present dissertation.

Chapter 2

Background

2.1 The auditory system – anatomy and physiology

The auditory system is divided into the peripheral and the central auditory system. The peripheral auditory system consists of the outer, the middle, the inner ear and the auditory nerve; and the central auditory system consists of the auditory pathways in the brainstem and the auditory cortex (Pickles, 1988).

2.1.1 The outer ear

The outer ear includes the pinna, the concha and the external auditory meatus. The airborne sound is picked up by the external constructs of the outer ear and transferred through the external auditory meatus to the tympanic membrane. The sound pressure at the tympanic membrane is amplified by acoustic resonance phenomena in the outer ear.

2.1.2 The middle ear

The filtered sound is transferred through the tympanic membrane into the middle ear. The airborne sound pressure affects the tympanic membrane and starts a mechanical movement of the ossicular chain leading the kinetic energy on to the oval window and the inner ear. The cavity of the middle ear is filled with air. The main functions of the middle ear and the ossicular chain is to compensate for the impedance difference between the air in the auditory meatus and the fluid in the cochlea of the inner ear, to minimise the energy loss, and to apply the force on the oval window only. The middle ear also includes two muscles which can affect the ossicular chain and the energy propagation. The stapedius muscle is attached to the stapes and the tensor tympani is attached to the malleus near the tympanic membrane. Both muscles increase the stiffness of the chain when they contract. Stapedius muscle contraction can be induced by high sound pressure levels or vocalisation and results in reduced sound pressure to the oval window mainly for frequencies below 1-2 kHz. The mobility of the tympanic membrane is optimal, high middle ear compliance, if the air pressure is equal on both sides. To provide a ventilation mechanism for the middle ear the eustachian tube connects the middle ear to the nasal cavity. By opening the eustachian tube, the air pressure in the middle ear is equalised to the air pressure in the nose.

2.1.3 The inner ear

The auditory function of the inner ear is based on the sensory function in the cochlea. The sound energy transmitted through the middle ear is applied on the oval window, the membrane leading into the cochlea. The cochlea consists of three cavities; scala vestibuli, scala media and scala tympani. The oval window is the entrance to the fluid filled scala vestibuli. The perilymphatic fluid in the scala vestibuli is also in connection with scala tympani at the apex of the cochlea. The basal part of scala tympani is closed by another membrane, the round window, which faces the middle ear cavity. Scala media is located in between scala vestibuli and scala tympani and contains endolymphatic fluid. Scala media and scala tympani are separated by the basilar membrane, on which the outer and inner hair cells are located. The tectorial membrane is located above the basilar membrane, covering the hair cells. A force on the oval window creates a wave motion in the fluid, generating a motion of the basilar membrane. This motion stimulates the hair cells. The maximum amplitude of the travelling wave occurs at different locations between the base and the apex depending on the frequency of the sound. High frequencies stimulate basal parts of the basilar membrane closest to the oval window and low frequencies stimulate the apical parts. Stimulation of an inner hair cell results in release of a neurotransmitter inducing electrical activity in the afferent nerve fibres in the auditory nerve.

In addition to the inner hair cells, outer hair cells are also stimulated by the motion of the basilar membrane. The main function of the outer hair cells is to mechanically enhance the motion of the tectorial membrane, in order to increase the stimulation of the inner hair cells (Brundin et al, 1989). This mechanism increases the audibility of low level sounds, but also contributes to the frequency resolution.

Due to the nonlinearity of the normally functioning cochlea, distortion components appear. When the ear is stimulated by two pure tones at various frequencies (f_1 and f_2), combination tones are produced. The cubic distortion tones appear at low stimulus sound pressure levels. The dominating cubic distortion product occurs at $2{\cdot}f_1\text{-}f_2$ and can be detected close to the hearing threshold. The amplitude of this cubic distortion tone is strongly dependent on the ratio between f_1 and f_2.

Both outer and inner hair cells are associated with afferent and efferent fibres of the auditory nerve. Inner hair cells are mainly connected to afferent nerve fibres, with their cell bodies in spiral ganglion, transmitting signals to the brainstem. Outer hair cells are also provided with afferent nerve fibres, however with appreciably fewer. The outer hair cells are mainly associated with efferent nerve fibres transmitting signals to the cochlea.

The efferent signals influence the length of the outer hair cells, which affects the stimulation of the inner hair cells through the tectorial membrane.

2.1.4 The central auditory system

The nerve signals from auditory stimuli propagate from the auditory nerve through the auditory pathways in the brainstem to the auditory cortex. On the way from the cochlea to the cortex the signals pass through different nerve nuclei. The number of nerve fibres increases and the signal analyses become more complex for each level in the central auditory pathways.

The primary auditory cortex represents perception and sensation of sounds and the associative auditory cortex processes linguistic stimuli and information of spoken language and other information-carrying sounds.

2.2 Hearing impairment

The sense of hearing can be impaired in different ways. Based on the location of the lesion the two main classes are central and peripheral lesions. Peripheral lesions, which are far more common than central lesions, are in turn separated into sensorineural and conductive lesions. Conductive lesions are due to disease or damage to the middle ear, while sensorineural lesions are located in the cochlea (cochlear lesion) and/or the auditory nerve (retrocochlear lesion).

A conductive hearing loss usually results in reduced sensitivity over the whole frequency range. It also affects the signal transmission to the same degree independent of the sound pressure level of the stimulus.

Damage to hair cells more commonly affects outer hair cells than inner hair cells. Typical damage to the hair cells includes stereocilia fracture, the actin filaments can become depolymerised, the tiplinks can break, the stereocilia may became detached and the cuticular plate may eject from the hair cell. Over the long term, the hair cells can degenerate completely.

Loss of outer hair cells reduces the ability to detect low level sounds, since the active amplification of motion of the tectorial membrane is reduced. The dynamic range of the auditory system will be reduced and the frequency selectivity impaired. The basally located outer hair cells are more sensitive than apically located, resulting in high frequency hearing loss dominating. A complete loss of outer hair cells would increase the hearing threshold by approximately 40-60 dB (Norton and Stover, 1994).

If the inner hair cells are damaged the sensory function will be reduced. Inner hair cell loss has been estimated to be present when a permanent threshold shift of 30 dB HL or more is present (Hamernik et al, 1989).

Since the ability to hear is crucial for spoken language, a hearing loss might affect speech communication considerably. An extensive loss of outer hair cells will increase the threshold for detection and perception of speech sounds, but will also reduce the audible dynamic range and the frequency resolution, and thereby the speech intelligibility. One major disability associated with outer hair cell loss is reduced ability to understand speech in masking background noise.

Hearing impairment may also appear as tinnitus, the perception of a sound (noise, tone) without an acoustic signal causing it. Tinnitus is considered to be caused by different factors. However, tinnitus is often associated with hearing loss.

2.2.1 Presbyacusis

Presbyacusis is a sensorineural hearing loss due to a normal age-related degeneration of the auditory system. The major cause of presbyacusis is reduced cochlear function, impairment or loss of hair cells. However, effects on the auditory nerve and the central auditory pathways are also common.

Outer hair cells are affected initially, even if pronounced presbyacusis also includes reduced function or loss of inner hair cells. Wright et al (1987) showed that for normal-hearing subjects the age-related loss of outer hair cells was larger than the loss of inner hair cells. The hair cell loss was most accentuated at the basal part of the basilar membrane. The lowest rate of outer hair cells degeneration occurs 17-26 mm from the basal end of the cochlea and increases both toward the apical and basal end, but is more pronounced toward the basal end (Bredberg, 1968).

In addition to direct damage or loss of hair cells, changes in the chemical balance in the cochlea may reduce the function of the hair cells, and thereby the auditory function. Mills et al (2001, 1990) have suggested atrophy of the stria vascularis, reducing the endocochlear potential, to be a possible factor for reduction of the hair cell function distinctively for age-related hearing loss. Spiral ganglion cells also show age-related changes, indicating neural degeneration of the cochlea (Mills et al, 2001).

The initial effect from presbyacusis is high frequency hearing loss, while more pronounced presbyacusis also affects the mid-frequency range. Increased hearing threshold results in reduced dynamic range, but also in reduced frequency selectivity due to outer hair cell loss.

Isolated age-related hearing loss has been suggested to be caused by vascular, metabolic or neural disorders (Mills et al, 2001). The degree of age-related hearing loss is individual. In a general population, hearing loss due to other factors than age would be expected. Hereditary factors might cause congenital or early progressive hearing loss or interaction with age-related deterioration. Some diseases, such as Menière’s disease, could also affect the auditory system. Other factors inducing hearing loss is exposure to hazardous noise, ototoxic drugs or ototoxic solvents.

2.2.2 Noise-induced hearing loss

Exposure to noise is a major factor causing hearing loss. Long term exposure to extensive noise damages the hair cells, which results in a cochlear hearing loss.

Extremely high sound pressure levels could rupture the tympanic membrane and instantly and permanently damage the hair cells in the cochlea.

Usually, noise-induced hearing loss initially affects the outer hair cells and the relation between outer and inner hair cells show predominantly outer hair cell loss (Hamernik et al, 1989). The propagating loss of outer hair cells starts in the part of the basilar membrane, corresponding to the frequency region around 4 kHz. An extensive noise-induced hearing loss affects larger areas of the basal outer hair cells and also inner hair cells. Loss of sensory hair cells may also result in secondary neural degeneration.

The disability from noise-induced hearing loss is similar to other sensorineural hearing loss. However, the shift in the hearing threshold in the range 3-6 kHz is characteristic (Quaranta et al, 2001; Taylor et al, 1965). The degree of susceptibility to noise is individual, as for age-related hearing loss.

Epidemiological studies have shown that noise-induced asymmetry between the ears, with poorer hearing threshold levels (HTL) in the left ear, is present and largest at 4 kHz (Pirilä et al, 1991a). An increased asymmetry with increasing HTLs has also been shown (Pirilä et al, 1991b; Chung et al, 1983).

Interaction effects are present between hearing loss due to age and to noise exposure. A model for the additional threshold shift due to noise exposure is described in ISO 1999 (International Organization for Standardization, 1990). Age-related and noise-induced threshold shift are considered additive, but a correction term is also included in the model. This term decreases the additive effect when the sum of the age-related and the noise-induced term is more than approximately 40 dB HL.

From studies on noise-exposed populations concerning both exposure duration and the subject's age it has been suggested that the effects from noise exposure are more evident in young subjects (Quaranta et al, 1998). Rösler (1994) compiled results from 11 investigations and concluded that for ages up to the thirties hearing loss is noise-induced. At an age of 35 to 40 years the age-related and the noise-induced components merge more and more in the audiogram. For higher age and for hearing loss exceeding 45 to 50 dB it is not possible to distinguish between the age and the noise effects and their additivity is no longer valid. Even though a correction term is used in ISO 1999 the noise-induced part might be overestimated when the total hearing loss exceeds 40-50 dB. In subjects older than 40 to 45 years and with hearing loss above 50 to 60 dB the hearing thresholds deteriorate slowly from additional noise exposure or increasing age. However, Miller et al (1998) suggest an increased effect from noise exposure with increasing age. They also show an increased sensitivity to noise for mice with early presbyacusis due to vascular pathology.

2.3 Audiometry in noise-induced hearing loss

When focus is on the measurement of cochlear function, two test methods are of primary interest: pure-tone audiometry and recording of otoacoustic emissions (OAE). The results of both methods are affected by the state of the middle ear, in particular otoacoustic emissions. Therefore it is important to know to what extent this interaction between middle ear and cochlear function occurs.

2.3.1 Tympanometry

In a normally functioning middle ear the sound transfer depends on the mobility of the tympanic membrane and the ossicular chain. The middle ear acoustic admittance describes for low frequencies the acoustic compliance, the elasticity of the system, and can be expressed as the equivalent volume of an occluded air-filled cavity. The compliance is largest when the static air pressure in the ear canal equals that of the middle ear cavity. This fact forms the basis for the indirect estimation of the middle ear pressure.

Tympanometry is the technique to determine middle ear compliance and middle ear pressure. A probe including earphone, microphone and pressure regulator is placed to occlude the ear canal. A low-frequency pure-tone, typically 226 Hz, is presented through the earphone and the sound pressure level of this probe tone in the ear canal is recorded while the static air pressure is varied. The middle ear compliance is presented as equivalent volume of enclosed air, where 1 cm^3 equivalent volume corresponds to about $1.00 \cdot 10^{-8}$ $m^3/Pa \cdot s$ acoustic admittance. The middle ear pressure is presented as divergence, in daPa, from the static air pressure (approximately 10 000 daPa).

2.3.2 Recording of otoacoustic emissions

When the normal outer hair cells are stimulated by a sound, they enhance the motion of the tectorial membrane and the inner hair cells. This active process of the outer hair cells creates a wave motion and an energy loss toward the basal part of the cochlea propagating through the middle ear. This acoustic signal can be detected and recorded as otoacoustic emissions in the ear canal. By evaluating the otoacoustic emissions from the cochlea, the function of the outer hair cells can be objectively determined. Three different methods for recording otoacoustic emissions are commonly used and named after how the signal is generated.

Spontaneous otoacoustic emissions (SOAE) are recorded without stimulation. A spontaneous activity of the outer hair cells creates narrow band emissions commonly detectable in the frequency range from 0.5 kHz to 9 kHz and with levels up to 30 dB SPL (Sininger and Abdala, 1998). The signals are recorded in the ear canal using a probe with a sensitive microphone. Signal analysis based on averaging of recorded frequency spectra provides the possibility to detect low level emissions in background noise. Spontaneous emissions are considered to be a natural phenomenon in a normal cochlea (Burns et al, 1992).

Otoacoustic emissions can also be detected after stimulating the cochlea. Using a probe containing both an earphone and a microphone an evoked otoacoustic emission can be recorded.

For transient evoked otoacoustic emissions (TEOAE) the energy propagation from the inner ear is detected after transient stimulation. To cancel linearly growing components of the response, and preserve nonlinearly growing components assumed to be TEOAE responses, a stimulus described as derived non-linear stimulus is commonly used. It consists of four clicks where one click has the opposite polarity and three times the peak sound pressure compared to the other three clicks. The purpose of this is to reduce the stimulus artefact in the recording. The level of the recorded TEOAE depends on the level of the stimulus.

The response is recorded within 20 ms after the stimulus click and reflects the activity of a large number of outer hair cells. The emission samples are stored in two records, A and B, and the TEOAE signal is determined from the mean value of two subsamples A and B: (A+B)/2. The noise level is determined from the difference of two subsamples: (A-B)/2. The emissions are evaluated from criteria on signal to noise ratio and the cross correlation coefficient between the two records. Depending on the signal analysis the response typically reflects the frequency range 0.5 kHz to 4 kHz.

The nonlinearity of the normally functioning cochlea can also be evaluated by measuring distortion product otoacoustic emissions (DPOAE). This method measures the distortion products produced by the outer hair cells when two tone stimuli are used. The cubic distortion tone with highest amplitude is present at $2 \cdot f_1 - f_2$ and can be recorded during the stimulation by means of spectral analysis. The amplitude of the distortion product depends on the ratio between f_1 and f_2 and the level of the two stimuli. Usually f_2 or the geometric centre frequency of f_1 and f_2 is used to represent the activity measured. A narrow band analysis of the signal at the frequency $2 \cdot f_1 - f_2$ provides criteria for true positive recordings of DPOAE.

For both TEOAE and DPOAE the prevalence of recordable emissions decreases with increasing damage or loss of outer hair cells. This provides the opportunity to evaluate the effects on outer hair cells from presbyacusis and noise-induced hearing loss.

2.3.3 Pure-tone audiometry

Pure-tone audiometry is a standardised and widely used clinical method for measuring auditory sensitivity. The hearing threshold levels that are measured in pure-tone audiometry primarily reflect the functional state of the peripheral parts of the organ.

The audiometer used for hearing threshold determination presents pure-tones through earphones or a bone vibrator to the test subject. Requirements of the equipment for pure-tone audiometry is specified in IEC 60645-1 (International Electrotechnical Commission, 2001) and calibration of the equipment is standardised according to ISO 389 (International Organization for Standardization, 1994). The procedure requires participation from the test subject, since it is based on the response to stimulation by pressing a button.

Hearing threshold measurements can be conducted according to different methods. An ascending procedure is standardised according to ISO 8253-1 (International Organization for Standardization, 1989). It is based on a criterion of at least 60% detection of monaurally presented stimuli. The stimulus level is increased from an inaudible level in 5-dB steps and the threshold is determined from the lowest level where three out of a maximum of five stimulations were detected. Frequencies in the range from 125 Hz to 8 kHz are evaluated for both the left and the right ear. The resulting hearing threshold level is described in dB hearing level, the deviation from a standardised average hearing threshold for otologically normal subjects aged from 18 to 30 years (International Organization for Standardization, 1994).

Results from the hearing threshold determination provide the opportunity to evaluate the degree of hearing loss at different frequencies. Age-related deterioration of the auditory function is generally present as threshold shift starting in the highest frequencies. Noise-induced hearing loss is characteristically detected as threshold shift in the frequency range 3 kHz to 6 kHz.

The reliability of pure-tone audiometry according to ISO 8253-1 (International Organization for Standardization, 1989) has been estimated to a test-retest mean difference close to zero with a standard deviation of 3-7 dB (Jerlvall et al, 1983).

For both OAE measurements and pure-tone audiometry the background noise level is crucial. Usually a sound-attenuating booth is used to minimise the ambient noise. The attenuation of the background noise also increases if insert earphones are used instead of supra-aural earphones. Maximum permissible sound pressure levels of the background noise in third-octave bands for the test environment are described in ISO 8253-1 (International Organization for Standardization, 1989). Attenuation data for the eartips ER 3-14, used for insert earphones EAR-tone 3A, have been presented by Berger and Killion (1989).

2.4 Noise

2.4.1 Exposure to noise

Noise is usually defined as unwanted sound. Noise exposure may result in differing effects on exposed persons depending on the noise level. Low level noise mainly induces speech interference or annoyance. At higher noise levels these effects increase, and in addition physiological effects may appear as well as effects on hearing in terms of hearing loss and/or tinnitus.

An octave band sound pressure level below 65-70 dB does not cause any temporary threshold shift (TTS), regardless of frequency or duration of the noise (Ward et al, 1976; Mills, 1982). Above the minimum exposure level for TTS and up to 120 dB SPL, TTS increases almost linearly with duration and level (Quaranta et al, 1998).

Standardised risk criteria for noise-induced hearing loss are presented in ISO 1999 (International Organization for Standardization, 1990). The risk criteria are based on sound pressure levels measured with A-weighting, to resemble the damage risk to the inner ear. The level of the noise that might induce hearing loss depends on the duration of the exposure. Based on a dose-effect assumption the critical level for noise-induced hearing loss is set to 85 dB(A) during 8 hours per day. However, the individual variation in susceptibility is large and even for this dose some subjects are likely to be affected. According to the equal-energy principle an increase by 3 dB would halve the permissible duration. This implies maximum 28 seconds noise exposure at 115 dB(A). For short lasting impulse sounds the peak level, regardless of the total energy, might cause a permanent threshold shift.

The Swedish legislation for occupational environments (Arbetarskyddsstyrelsen, 1992) specifies the exposure limits to equivalent sound pressure level of 85 dB(A) during 8 hours, five days a week, maximum sound pressure level of 115 dB(A) and maximum peak level of impulse sound of 140 dB(C). Similar legislation exists for the European Union (European Communities, 1986) and the United States (Occupational Safety and Health Administration, 1981).

2.4.2 Exposed groups in the society

Noise-induced hearing loss is one of the most prevalent occupational diseases in many countries. In developed countries more than one third of the hearing impairments are partly caused by excessive noise exposure (Smith, 1998). In 2001, 22.5% of the employed population in Sweden stated that they were exposed, at least one fourth of the working time, to noise of levels that prevented them from speaking with normal effort (Swedish Work Environment Authority, 2002a). The number of exposed women has increased during the 1990s. Noise-induced hearing loss was the fourth most common occupational disease in Sweden in 1999. Approximately 5% of the reported occupational diseases in 1998, 1999 and in 2000 were caused by noise exposure (Swedish Work Environment Authority, 2002b). In 2000, 1.6% of the employed population stated that they had had work-related health problems during the last twelve months due to noise (Swedish Work Environment Authority, 2000). The corresponding figure in 2001 was 1.4%.

The most common source of occupational noise causing hearing loss is handheld machines or tools, vehicles and metal or wood processing machines (Swedish Work Environment Authority, 2001). Occupational environments with high noise exposure are, for example, metal-production, mechanical and wood processing industries. Men are more exposed than women and the prevalence of noise-induced occupational disease is also higher among men. In addition to the occupational disease, a large portion of reported noise-induced hearing impairment comes from male subjects exposed during their military service.

Leisure time noise might constitute an essential part of the total amount of a subject's exposure to hazardous noise. One major group of leisure time noise-exposed subjects is sport shooters, and hunters in particular. Another major exposed group is amateur musicians. Attending heavily amplified music concerts and discotheques might also induce hearing loss and/or tinnitus. Other potentially damaging leisure noise sources are, for example, power tools, lawn mowers and motor sport activities.

2.5 Reference data

Reference data are needed to allow comparisons between test results obtained in a noise-exposed population and those from the non-exposed reference population. Thus, the reference population should contain no subjects with occupational noise exposure which might have affected their hearing, but all other factors that might affect hearing should be included.

2.5.1 Criteria for good reference data

The International Organization for Standardization, ISO, has presented reference data for HTLs as a function of age in ISO 1999 (International Organization for Standardization, 1990). Two different data bases are described: data base A for otologically highly selected populations and data base B for otologically unselected populations, not exposed to hazardous occupational noise. In data base A the populations studied have been screened for ear pathology and history of undue exposure to noise. The data base A equals the reference data in ISO 7029 (International Organization for Standardization, 1984) and only describes the age-related shift in HTL for male and female subjects relative to the age 18 years. If the effect from hazardous occupational noise exposure is investigated, reference data are needed of a population not exposed to hazardous occupational noise, but in all other aspects representative for a general population. Such a data base of age-related threshold shift in male and female subjects in the USA is described in ISO 1999 (International Organization for Standardization, 1990) data base B. Since environmental, hereditary and disease factors may differ from one country to another, a national data base is preferable, reflecting the situation in the specific country. A natural variation in HTL is present for all general populations. Therefore the statistical distribution of HTL values must be known.

To establish a relevant reference data base B a population based study of randomly selected subjects is preferred. The only exclusion criterion for the population included in the data base should be hazardous occupational noise exposure.

A reference data base for OAE is more complicated. To date, parameter values for stimulus, signal-to-noise criteria for true positive OAE detection, methodology for signal analysis and presentation of the recordings are not standardised. This makes comparison between different studies complicated at best.

2.5.2 Previous studies and results

In ISO 1999 (International Organization for Standardization, 1990), a data base B is described. An example for the USA is given, based on a study by Johnson (1978). However, these data do not necessarily apply to Swedish populations. Unpublished studies from our laboratory have shown that the example of data base B in ISO 1999 overestimates the HTLs in corresponding populations in Sweden.

In 1988 Robinson (1988) described HTLs for an otologically unscreened population, based on two different studies. The first, by Glorig and Roberts (1965), investigated a random sample of the USA general population. The second, by Sutherland and Gasaway (1978), investigated civilian employees of the US Air Force. A systematic difference was observed between these two populations in the 30-, 40- and 50-year age spans, and in these age groups only the better HTLs of the two populations were used. These data presented by Robinson (1988) show a large discrepancy from seven more recent studies of otologically unscreened populations in the Netherlands, Germany, Hong Kong, France and the USA (Passchier-Vermeer, 1988). Although some differences are present, these more recent studies correspond reasonably well with each other. The discrepancy between the results of Robinson (1988) and of Passchier-Vermeer (1988) may be explained by occupational noise exposure of some of the test subjects, audiometric test conditions, and differences in information and motivation of the test subjects (Passchier-Vermeer, 1988).

Passchier-Vermeer (1988) also presented correction values for the 10th, 50th and 90th percentiles of the HTLs in ISO 7029 (International Organization for Standardization, 1984), to allow the use of these data as data base B. However, even if this correction was an improvement, most of the studies underlying this correction were not based on randomly selected populations.

In 1995 a large-scale study on a randomly selected population in Great Britain was published (Davis, 1995). The material was divided into data sets with no exclusion criteria, and data sets with subjects who had no significant noise exposure occupationally, from gunfire, or from social contexts. The first data set therefore probably shows better HTLs and the second data set worse HTLs than a general population only selected by excluding occupational noise exposure.

However, no relevant HTL reference data base for an otologically unscreened, non-occupationally noise-exposed population in Sweden is present.

Reference data on tympanometry measurements have been published for different populations. Margolis and Heller (1987), Hall (1979), Jerger et al (1972), Brooks (1971), Burke et al (1970), Bicknell and Morgan (1968) and Feldman (1967) have all published data for middle ear compliance. Hall III and Chandler (1994) reviewed published data for middle ear pressure. However, most studies have been conducted on populations that were not randomly selected.

For OAEs the lack of standardised parameters has reduced the possibility to present reference data. Most published studies concern different selected populations. However, for specified sets of test characteristics, prevalence data over SOAEs, TEOAEs and DPOAEs are available.

Prevalence of SOAEs among normal-hearing subjects has been described by Stover and Norton (1993), Moulin et al (1993), Burns et al (1992), Probst et al (1991), Kemp et al (1990), Martin et al (1990), Lind and Randa (1990) and Bilger et al (1990). About 40% to 60% of normal-hearing subjects have detectable SOAEs. However, none of these studies concerned randomly selected populations, but selected normal-hearing populations. Probst et al (1987) investigated the presence of SOAEs in subjects with different degree of hearing loss and found that for ears demonstrating SOAEs the estimated HTLs were always less than 20 dB HL at the emitted frequencies.

For TEOAEs, studies have shown high prevalence in normal-hearing populations (Probst et al, 1991). The absence of recordable TEOAEs in subjects with average hearing threshold level over the frequencies 0.5, 1, 2 and 4 kHz worse than 35-45 dB HL has also been shown (Bonfils and Uziel, 1989; Collet et al, 1989; Probst et al, 1987). Similar results have been presented for DPOAEs with reliably recorded emissions in the frequency range 1-8 kHz in normal-hearing subjects (Martin et al, 1990; Lonsbury-Martin et al, 1993).

However, not many studies are available concerning reference data for randomly selected populations separated by age and gender. Engdahl (2002) presented a large scale study on an unscreened adult population in Norway. Results for both TEOAE and DPOAE were described as a function of age, gender and ear side. A similar study of TEOAEs has been conducted in an Australian population (Murray and LePage, 1993). Gates et al (2002) conducted a large scale study based on volunteer members of the Framingham Offspring Cohort in USA, but excluded subjects with non-age-related hearing loss or middle ear disease. Most published studies concerned pre-selected populations.

2.6 Purpose of the dissertation

This dissertation aims to illustrate the effects from occupational noise exposure on hearing and to improve the basis for evaluating such effects by comparison with reference data. Noise has obviously a serious impact on hearing and may cause hearing impairment in terms of hearing loss and tinnitus. The working environment is a major factor for noise-induced hearing loss and noise is the source of one of the most prevalent occupational diseases in many countries. The first part of the present work investigates the changes over time in hearing thresholds and the present state of the HTLs in two occupationally noise-exposed groups. Factors affecting the HTL changes are also evaluated.

Relevant reference data are crucial for evaluation of hearing loss due to occupational noise exposure. Since no such data were available the second part of the present work was initiated. In addition to descriptive data for HTLs, a more realistic mathematical model than that presented in ISO 7029 (International Organization for Standardization, 1984) describing the age-related threshold shift, was also introduced.

When the hearing ability has deteriorated to a certain degree, caused by presbyacusis and/or noise exposure, rehabilitation is necessary. To accurately delineate the presence of hearing impairment in Sweden, a third study was initiated. It aims to describe the prevalence of different degrees of hearing loss and tinnitus in a general adult population, not exposed to hazardous occupational noise. The results provide a base for estimation of rehabilitation needs and the number of potential hearing aid candidates.

The most vulnerable component of the auditory system is the outer hair cells. Both ageing and noise exposure affect their functionality. Otoacoustic emission measurements are used both experimentally and clinically to evaluate outer hair cell function. However, reference data are missing partly due to lack of parameter standardisation. The last part of the present work aims to evaluate SOAE, TEOAE and DPOAE results and how these are related to age and gender in a general adult population.

Tympanometry is a method, describing the state of the middle ear, which is of relevance in particular for OAE measurements. The present work also aims to investigate the relation between OAE measures and tympanometry results and to present reference data for middle ear pressure and middle ear compliance in a general adult population.

Chapter 3

Contribution of the present work

3.1 Aims of the studies

3.1.1 Paper A

The aims of *Paper A* were to investigate changes over time in HTLs for subjects exposed to occupational noise, to compare these results to reference data of non-occupationally noise-exposed subjects, and to evaluate the influence of factors such as hearing protector use and military noise exposure on the results.

3.1.2 Paper B

The main aim of *Paper B* was to create a reference data base of HTLs for an otologically unscreened population in Sweden, not exposed to hazardous occupational noise. Secondary aims were to generate a mathematical model for the age-related HTL shift and to investigate how age, gender and ear side affects HTL for different pure-tone frequencies.

3.1.3 Paper C

The aim of *Paper C* was to determine the prevalence of the different degrees of hearing loss and prevalence of tinnitus in an otologically unscreened population in Sweden, not exposed to hazardous occupational noise. The aim was also to validate different pure-tone averages, the influence of HTLs at the frequency 3 kHz on these estimates and to estimate the number of subjects potentially benefiting from hearing aids.

3.1.4 Paper D

The aim of *Paper D* was to investigate SOAE, TEOAE and DPOAE prevalence and response mean data covering effects from age, gender, ear side and HTL in an otologically unscreened population in Sweden, not exposed to hazardous occupational noise. The aim was also to determine reference data for middle ear pressure and middle ear compliance for the population under study. A third aim was to investigate the relation between the different OAE measures and middle ear pressure and compliance.

3.2 Materials and methods

3.2.1 Paper A

The first paper is a retrospective cross-sectional study concerning HTLs in subjects from two occupational environments: mechanical industries and wood processing industries. Male subjects aged from 30 to 59 years were selected from the existing HTL data base in the province of Östergötland in Sweden. The HTLs for subjects in the three age groups (30-39, 40-49 and 50-59 years) were compared over three decades. The audiograms were recorded from 1971 to 1976, from 1981 to 1986 and from 1991 to 1996. All subjects were exposed to occupational noise more than two hours a day at their present work according to subjective assessment. In total, 15,058 audiograms were included in the analysis.

Hearing threshold levels by air conduction were recorded according to the screening procedure specified in ISO 8253-1 (International Organization for Standardization, 1989). The measurements were conducted either at different occupational health centres or in a mobile unit equipped with a soundproof booth. The audiometers were equipped with TDH-39 or TDH-49 earphones and calibrated according to ISO 389-1 (International Organization for Standardization, 1998) or relevant earlier editions annually. Results from right and left ears at the frequencies 2, 3, 4, 6 and 8 kHz were included in the statistical analysis.

The data were presented as median and quartile values of HTLs according to Winkler and Hays (1975). The changes over time for different frequencies, in left and right ears, and in different age groups, were investigated using non-parametric statistical analysis and the results were compared to most suitable reference data to that date (International

Organization for Standardization, 1984; Passchier-Vermeer, 1993). Prevalence of normal-hearing subjects was determined according to criteria described by Klockhoff et al (1974) and reference data according to Passchier-Vermeer (1993).

In addition to audiometry all subjects answered a questionnaire regarding noise exposure, military service and use of hearing protectors.

3.2.2 Papers B-D

All three papers B, C and D were based on the same study population, although the number of subjects differed slightly between the papers. The exclusion criteria were the same in all three papers, but the age range differed somewhat since all subjects did not complete all measurements.

All subjects were selected using the Swedish personal number register, which is based on birth date and a four-digit security number. A sample based on subjects born on the 9^{th} or the 24^{th} was selected and reduced to a reasonable number by additional selection on the last security digit. This procedure generated a demographically representative sample of the population in the province of Östergötland, which is a demographically representative province of Sweden as well.

To represent a general adult population, no otological selection was performed. However, to fulfil the purpose of the study and to create a reference data base with HTLs for subjects not exposed to hazardous occupational noise, a selection criterion on occupational noise exposure was used. The selection was based on subjective assessment of the ability to speak to another person at a distance of one meter in the present and in former working environments (see *Appendix I*).

Under the selection procedure described above, 1863 subjects were invited to participate. Of these 846 responded and 823 agreed to participate. In total, 646 came for the hearing examination and filled out the questionnaire and after applying the exclusion criterion to the group 603 subjects were included in the analysis. In *Paper B* the age range for these 603 male and female subjects was 19 to 81 years. In *Paper C* the same sample population was used, but the age range was limited from 20 to 80 years resulting in 590 subjects. In *Paper D* the same sample was used, but a smaller number of the subjects completed the whole test battery including OAE measurements. In total, 493 subjects aged from 20 to 80 years were included in the analysis.

The same test battery was used with all subjects, however, each of *Papers B, C* and *D* focused on different aspects of the results. Otoscopic examination was conducted of the ear canal and tympanic membrane. Tympanometry was performed, using an American Electromedics Corporation 85 AR tympanometer, to determine the middle ear pressure and the middle ear compliance. A descending pressure sweep was used with a probe tone of 85 dB SPL at 226 Hz. The equipment was calibrated according to the manufacturer's guidelines.

Pure-tone audiometry was conducted according to the ascending procedure described in ISO 8253-1 (International Organization for Standardization, 1989), using a Grason-

Stadler GSI 68 audiometer and EAR-tone 3A insert earphones. Left and right ears were examined for the frequencies 0.125, 0.25, 0.5, 1, 1.5, 2, 3, 4, 6 and 8 kHz. The equipment was calibrated according to ISO 389-2 (International Organization for Standardization, 1994).

Three different kinds of otoacoustic measurements were recorded: spontaneous, transient evoked and distortion product otoacoustic emissions. For these measurements, a Madsen Electronics Celesta 503 Cochlear Emissions Analyzer was used.

The SOAEs were recorded in the frequency range from 0.5 kHz to 10 kHz with a frequency resolution of 12.7 Hz. An S/N ratio of 4 dB was used as criterion for an SOAE to be considered present.

For the TEOAE recordings, stimulation in the derived non-linear mode was used consisting of one click with the opposite polarity and three times the peak sound pressure of the following three clicks. The peak sound pressure level of the stimulus with largest amplitude was 70 dB SPL. The TEOAEs were analysed both as broad band response (0.5-4 kHz) and in three octave bands (0.5-1 kHz, 1-2 kHz and 2-4 kHz). A 12 ms time window, starting 6 ms after the stimulus, was used with a sample rate of 26.04 kHz and resolution of 50.9 Hz.

The DPOAEs were recorded at eight distortion product frequencies (0.53, 0.71, 1.06, 1.41, 2.12, 2.83, 4.26 and 5.68 kHz) generated from stimuli at two frequencies, f_1 and f_2, were $f_2/f_1=1.22$ and the geometric centre frequencies of f_1 and f_2 corresponded to the audiometric frequencies (0.75, 1, 1.5, 2, 3, 4, 6 and 8 kHz). The stimulus levels L_1 and L_2 were 70 dB SPL. The recorded signal level was determined at a sample rate of 6.51 kHz and 3 Hz resolution for the DP-frequencies 0.75-1 kHz, sample rate 13.02 kHz and 6.3 Hz resolution for 1.5-3 kHz, and sample rate 26.04 kHz and 12.7 Hz resolution for 4-8 kHz. The noise level was determined from the average of 10 frequency bands below and 10 frequency bands above the DP-frequency band, where the two nearest frequency bands on each side of the DP-frequency band were excluded.

For all OAE measurements a Madsen Electronics OAE probe was used, calibrated by the manufacturer.

All audiometric and otoacoustic emission measurements were conducted in one of three different clinics in the province, or in a mobile unit. In all locations a sound-attenuating booth was used to reduce the background noise level to allow measurement of HTLs down to at least 0 dB HL.

In addition to these measurements, a questionnaire regarding noise exposure, tinnitus, hearing aid use and other hearing-related information was used (see *Appendix I*). One audiologist conducted all tests.

In *Paper B* the statistical analysis consisted of MANCOVA and Tukey honest significant difference test for unequal sample size for determining effects from age, gender, ear side and frequency on the HTL. The mathematical model for describing the age-related change in HTL was determined by regression analysis on smoothed HTL-curves. The data were fit to hyperbolic tangent functions in a model with four parameters.

In *Paper C* the prevalence of subjects with different degrees of hearing loss was determined for average values of HTLs at 0.5, 1, 2 and 4 kHz (M4) and at 0.5, 1, 2, 3 and 4 kHz (M5) for the better (BE) and the worse ear (WE). The degree of hearing loss was divided into five categories according to the European Working Group on Genetics of Hearing Impairment (Martini, 1996). Correlation was determined between average values of HTLs at 0.5, 1, 2 kHz (M3) and M4, between M4 and M5, between HTL at 3 kHz and M4, and between prevalence of hearing loss for M4 and M5. The prevalence of prolonged spontaneous tinnitus lasting for more than five minutes was also determined. For both hearing loss and tinnitus, logistic regression analysis was used to determine odds ratios for different age groups and gender.

In *Paper D*, middle ear pressure and middle ear compliance were analysed using ANOVA with repeated measures, with ear side as within-subject factor and age group and gender as independent variables. The number of subjects with SOAEs was analysed using Chi^2-test and Wilcoxon matched pairs test. The mean values and standard deviations of TEOAE and DPOAE responses were described in different age groups, gender and ear side for different response frequencies. Effects on the response level from the group variables were determined from MANOVA and MANCOVA with HTL as covariate variable. To determine skewness Shapiro-Wilk W-test was used and all post hoc comparisons were conducted with Fischer's LSD test.

3.3 Results

3.3.1 Paper A

There was a positive trend in the HTL change over time. In both the mechanical work group and the wood processing group, the improvement from the 1970s to the 1990s was statistically significant. The changes were most pronounced in the group of mechanical work, but in the 1990s both occupational groups showed similar HTLs for all age groups.

For all groups in which an HTL difference occurred, the left ear showed the poorest result. During the 1970s and 1980s both occupational groups showed poorer HTLs at 6 kHz compared to 8 kHz, but in the 1990s this frequency difference was statistically significant only for mechanical workers.

Prevalence of normal-hearing male subjects, based on the classification according to Klockhoff et al (1974), increased over time. The results were still lower compared to reference data of non-occupationally noise-exposed male subjects (International Organization for Standardization, 1984; Passchier-Vermeer, 1993).

The use of hearing protectors increased over time among mechanical workers. In the 1990s the prevalence of stated hearing protector use was similar for both occupational groups. More than 80% of the subjects in all age groups used hearing protectors, even if the use was lower in the oldest age group compared to the other two groups.

3.3.2 Paper B

Age group and gender showed statistically significant main effects and interaction effects on HTL. The HTL was worse in the older age groups compared to the younger. The threshold shift appeared to be larger above 60 years for frequencies below 3 kHz and above 50 years for frequencies above 3 kHz. The HTLs at 2 kHz and above were worse for male subjects compared to female subjects. The interaction effect between age and gender showed a statistically significant gender difference, with 11-18 dB worse HTLs for male subjects above 50 years at 3 and 4 kHz and in the age groups 50-70 years at 6 and 8 kHz. No systematic ear side effect or statistically significant post hoc effect was present.

The age-related shift in HTL was determined and described using a hyperbolic tangent function:

$$HTL = A' + B' \cdot \tanh(C \cdot Age + D)$$

The parameter values A’, B’, C and D are listed in *Paper B*, table 3a-r, for female and male subjects, for frequencies 0.125 to 8 kHz, and for nine percentiles from the 10th to 90th. The HTL values based on the mathematical model and the parameter values presented are tabulated in *Appendix II*. Examples of the HTLs at different ages, determined as nine percentile curves, are shown in *Paper B* figure 2b for female subjects at 4 kHz and figure 3b for male subjects at 4 kHz.

3.3.3 Paper C

The prevalence of hearing loss described as M4≥25, 35, 45 and 65 dB HL is shown for female and male subjects’ better and worse ear in *Paper C*, table 2 and 3. The overall prevalence of female and male subjects with M4 BE≥25 dB HL was 16.9%. The prevalence of more pronounced hearing loss was 3.3% for M4 BE≥45 dB HL and 0.2% for M4 BE≥65 dB HL. If the hearing loss is defined as mild hearing impairment (Martini, 1996), the prevalence was 16.2% for female subjects and 20.5% for male subjects. The prevalence of mild, moderate, severe and profound hearing loss was 20.9% collectively for female subjects and 25.0% collectively for male subjects.

The prevalence of hearing loss increased with age above 50 years. The odds ratios for M4 BE≥25 dB HL and M4 BE≥45 dB HL are shown in *Paper C*, table 5. The odds ratios for hearing loss difference between male and female subjects were not statistically significant.

Tinnitus was reported with a prevalence of 8.9% among female subjects and 17.6% among male subjects. The prevalence difference between male and female subjects was statistically significant with odds ratio 2.2 ($p<0.001$). Reported tinnitus also increased with statistical significance with increasing age (see *Paper C*, table 5).

The correlation between the hearing loss prevalence based on M4 and M5 was high ($r^2=0.99$, $p<0.01$). The correlation between M5 BE and M4 BE results and the correlation between M4 BE and M3 BE results was also high ($r^2=0.99$, $p<0.01$ and $r^2=0.94$, $p<0.01$, respectively). The contribution from the frequency 3 kHz to M5, to improve in the accuracy over M4, was shown as a dispersion in the correlation between HTL at 3 kHz and M4 BE in *Paper C*, figure 4. The correlation coefficient was $r^2=0.81$ ($p<0.01$).

The questionnaire showed that 2.4% of the population under study were hearing aid users.

3.3.4 Paper D

The distribution of middle ear pressure and middle ear compliance was determined and described in *Paper D*, figure 2,3. The median middle ear pressure was -13 daPa with a lower quartile value of -25 daPa and an upper quartile of -3 daPa. The median middle ear compliance was 0.71 cm^3 with a lower quartile value of 0.50 cm^3 and an upper quartile value of 1.00 cm^3. No general effect from age group, gender or ear side was present for either middle ear compliance or pressure.

The prevalence of ears with SOAEs was 25% and the prevalence of subjects with at least one ear with SOAEs was 37%. Female subjects showed a statistically significant higher prevalence than male subjects, but no effects were present according to age group, ear side, middle ear pressure or middle ear compliance. Spontaneous otoacoustic emissions were most commonly present in the frequency range 1 to 2 kHz.

Prevalence of recordable TEOAEs and mean signal levels for the TEOAEs are described in *Paper D*, table 2, for the population under study. The broad band TEOAE prevalence in the whole population was 53% for left ears and 58% for right ears. Prevalence of octave band responses was similar in the frequency band 1-2 kHz, but lower in both the 2-4 kHz and the 0.5-1 kHz band. Transient evoked otoacoustic emissions prevalence was highest in the youngest age groups.

The effect from the group variables gender, age, ear side, middle ear pressure and middle ear compliance on the TEOAE mean signal level was determined. A gender difference was present, even after adjusting for the covariate HTL, with 2-3 dB higher level for female subjects compared to male subjects. Increasing age resulted in decreasing TEOAE signal level. After adjusting for the age-related shift in HTL, the shift in TEOAE signal level remained for left ears and was most pronounced between the age groups 20-29 and 30-39 years. A slight ear side effect was also observed with higher signal levels in right ears. High middle ear compliance resulted in lower TEOAE signal level by about 2 dB after adjusting for differences in HTL.

DPOAE prevalence values and mean signal levels were determined for eight distortion product frequencies, see *Paper D*, table 4, 5. The overall prevalence of subjects with recordable DPOAEs ranged from 65% at 8 kHz to 93% at 1.5 kHz. As for TEOAEs the prevalence of DPOAEs was highest in the youngest age groups.

The group effects on DPOAE signal level were similar to the effects on TEOAE signal level. A gender difference, with higher levels for female subjects, was present for the geometric centre frequencies 2 and 3 kHz after adjusting for HTLs. An age effect was present for the frequencies 4, 6 and 8 kHz, with decreasing signal level with increasing age. As for TEOAE signal levels the age effect on DPOAE signal level was most pronounced between the youngest age groups. No general ear side effect was present after adjusting for the HTL. Middle ear compliance affected the DPOAEs for the frequencies between 1.5 kHz and 4 kHz. High middle ear compliance values resulted in lower DPOAE signal levels.

3.4 Discussion

3.4.1 Paper A

Since the audiograms were recorded using different screening levels of 0, 10 and 20 dB, it was not possible to determine the accurate median HTL in all groups. However, this concerns only the youngest age groups and does not influence the improvement over time determined in the older age groups. It was also possible to determine an improvement over time for the 3rd quartile values of HTLs in all groups.

The notation that noise-induced hearing loss has decreased over the time period the 1970s to the 1990s, was supported by the fact that the improvement of HTLs was larger for the frequency 6 kHz compared with the frequency 8 kHz.

An ear side difference in HTL was observed in several groups, and in all these groups the left ears were the poorest ones. This phenomenon has been observed in several studies on noise-exposed populations (Pirilä, 1991; Pirilä et al, 1991a) without consensus on the factors causing the difference. However the ear side difference is not present in general populations, not exposed to hazardous noise (Passchier-Vermeer, 1988; Rosenhall et al, 1990). This is also what the results from *Paper B* show.

The reference data used in the study was the ISO 7029 (International Organization for Standardization, 1984) with corrections according to Passchier-Vermeer (1993). This was in our opinion the most proper reference data at that time. However, reference data from a general population, not exposed to hazardous occupational noise, would be a better alternative. In the ISO 1999 standard (International Organization for Standardization, 1990), a national data base of an otologically unscreened population, not exposed to hazardous occupational noise, is proposed, but no reliable national or international reference data base was available at that time. The lack of relevant reference data was an incentive to *Paper B*.

Based on the reference data used in the study the results showed that still in the 1990s the HTLs were poorer than expected for a not-noise-exposed population. If the prevalence of normal-hearing is compared to the reference data from *Paper B* (tabulated in *Appendix II*), the results are similar. The results from *Paper B* show that the percentile of 39 year-old male subjects with HTL≤25 dB HL at 6 kHz is between 80 and 90, of 49 year-old between 60 and 70, and of 59 year-old between 30-40 (table 1).

Age group	*Mechanical work*	*Wood processing*	*ISO 7029 corrected*	*Paper B*
30-39	66%	57%	82%	>80%
40-49	34%	28%	61%	>60%
50-59	13%	11%	35%	>30%

Table 1. *Prevalence of subjects with HTL≤25 dB HL at 6 kHz in the population under study in the 1990s, in reference data ISO 7029 (International Organization for Standardization, 1984) corrected according to Passchier-Vermeer (1993), and in reference data from Paper B. Reference data represent male subjects 39, 49 and 59 years old, i.e. worst case within each age group.*

If the median HTLs at 6 kHz are compared to reference data in *Paper B* the results also show that still in the 1990s the HTLs were poorer than expected (table 2). In all three age groups the median HTL is about 10 dB worse than among subjects not exposed to hazardous occupational noise.

Age group	*Mechanical work*	*Wood processing*	*Paper B*
30-39	18.3	17.5	8.6
40-49	25.0	29.2	17.9
50-59	41.4	43.9	33.6

Table 2. *Median HTL [dB HL] at 6 kHz in the population under study in the 1990s and in reference data from Paper B. Reference data represent male subjects 39, 49 and 59 years old, i.e. worst case within each age group.*

However, even if the prevalence of normal-hearing and the median HTLs are worse in the noise-exposed groups compared to not-exposed subjects, the HTLs have improved over time. Proposed explanations to the positive trend from the 1970s to the 1990s are an increased knowledge of the risk of loud noise and the increased use of hearing protectors.

It also became clear that the ability to perform long-term studies of changes in HTLs in relation to the occupational environment is very limited. The data base of audiograms used in the study is one of, if not the only one, still in use in Sweden. In order to successfully prevent occupational hearing loss, monitoring, evaluation and feedback is necessary, but the lack of data bases in use may seriously reduce this possibility in the future.

This study was conducted in 1999, and the reason why the time-period under study was limited to 1997 was a decreasing input of audiograms to the data base after 1997. However, the data base is still in use and will hopefully provide data for future research.

3.4.2 Paper B

The results from *Paper B* provide the opportunity to evaluate the effect on hearing thresholds from hazardous occupational noise exposure. This reference data base fulfils the specifications according to ISO 1999 (International Organization for Standardization, 1990) as a reference data base B and meets the requirements from the staff in occupational health care centres.

When analysing the data the variables age and gender influenced the results. For high frequencies (>3 kHz) a gender difference occurred above an age of 50 years, with better HTLs for female subjects. This result implies the use of different reference data for male and female subjects. The large gender difference, of between 11 to 18 dB, also raises the question of why there is a gender difference. One possible explanation might be military noise exposure among male subjects. As shown in *Paper A* the use of hearing protectors among military noise-exposed men increased during the 1970s. For subjects born before 1950 the hearing protector use during military service was considerably lower than for subjects born after 1950. In *Paper B* the large gender difference occurs in age groups born before 1950. When looking at the results from the questionnaire in *Paper B*, both the percentage subjects participating in military service and the percentage military noise-exposed who never used hearing protectors, were higher among men born before 1950 compared to men born after 1950.

Since no general effect from ear side on HTL was present in the population, the data from left and right ears were merged together in the mathematical model described. Previous studies on noise-exposed subjects have shown an ear side effect, with poorer HTLs in left ears (*Paper A*; Pirilä et al, 1991a, b; Chung et al, 1983). These results suggest that ear side difference in HTL for group data is associated with noise exposure, and should be considered as an indicator for a hazardous noise environment.

In the statistical analyses, ear was considered as an independent variable with left and right ears as independent observations. It could be claimed that the left and the right ears are not independent and that there is a correlation between the right and the left ear for each subject. To take this potential correlation into consideration, a variable with a unique number for each subject was introduced and used as a covariate variable in the MANOVA. However, this covariate had no influence on the results.

The results were compared to previous reference data from Davis (1995) and Passchier-Vermeer's (1988) correction of ISO 7029 (International Organization for Standardization, 1984). The median HTL at 4, 6 and 8 kHz correspond reasonably well to Passchier-Vermeer's (1988) data. Compared to Davis' (1995) data, differences in HTL was observed at 6 kHz ranging from 7 to 16 dB. Besides possible bias from noise exposure, the difference might partially be explained by the use of different earphone types and known problems related to resonance and calibration of Telephonics TDH-39 supra-aural earphones with different cushions.

To make the reference data useful, a mathematical model was determined. Compared to previous models, as in ISO 1999 (International Organization for Standardization, 1990), a more realistic one is introduced in *Paper B*. The hyperbolic tangent function steadily increases from a minimum baseline to a maximum finite value with a maximum rate of change in between these values. Expressed as exponential functions the model is easier to relate to physiological or biological processes compared to the polynomial function used earlier. The results clearly show an increase in threshold shift with increasing age up to a point where the threshold shift starts to decrease with age. For the poorest HTL percentile the values reach a maximum asymptotic value in the higher ages.

When using the results from *Paper B* the mathematical model allows the estimation of HTLs at each year of age from 20 to 79 years. The model also includes the dispersion in HTL at each age. Nine different percentile curves are determined for the data, describing an increasing dispersion with increasing age. The median curve describes the expected HTL, where half of the population show better, and half of the population poorer HTLs, compared to this value. However, when using the model some subjects still evidence poorer HTL, and others better HTL, because of hereditary factors, vulnerability to noise, and other factors.

Parameter values for the model describing the reference data are determined for the ten audiometric frequencies, male and female subjects, and nine percentile values in *Paper B*. The HTLs generated from the model and the listed parameter values are tabulated in *Appendix II*. A downloadable version of the tabulated HTLs is also available at the Swedish Work Environment Authority web site, to make the results easily accessible (http://www.av.se/publikationer/bocker/fysiskt/h293.shtm).

3.4.3 Paper C

In *Paper A* the hearing loss was categorized according to Klockhoff et al (1974). This method does not take into account the age-related threshold shift. In *Paper C* the prevalence of different degrees of hearing loss was evaluated with respect to age and gender. In older age groups we do not expect what is classified as normal-hearing according to Klockhoff et al (1974), but a normal degree of hearing loss. The results show the expected prevalence of hearing loss in different age groups if subjects were not exposed to hazardous occupational noise. When investigating noise-exposed populations, this prevalence of defined hearing impairment should be expected if the noise exposure has not caused any damage. The results also offer the opportunity to determine the demand for rehabilitation.

The overall results of prevalence of hearing loss are similar to studies of general populations in Great Britain (Davis, 1989), Italy (Quaranta et al, 1996) and Australia (Wilson et al, 1999). No statistically significant gender difference in prevalence of hearing loss was present according to the logistic regression. In both the British (Davis, 1989) and the Australian study (Wilson et al, 1999) a gender difference was present, with higher odds ratio among male subjects. However, when comparing the HTLs *Paper B* shows that a gender difference was present in subjects older than 50 years.

The results show that 7.7% of the population have M4 BE≥35 dB HL and are considered to possibly benefit from hearing aids. Similar results have been shown for the British population (Davis, 1995), with a prevalence of 8.2%, and in Australia (Wilson et al, 1999), with a prevalence of 6.9%, for the same degree of hearing loss. However, when investigating the number of hearing aid users in the population under study, the portion was only 2.4%. Similar values have been estimated for Denmark, Finland, Norway and the United Kingdom (Barton et al, 2001). In the present study the estimated portion of subjects in Sweden provided with hearing aids was 2.8%. If the criterion was more restrictive and changed to M4 BE≥45 dB HL the prevalence would be 3.3%, which is closer to what is estimated as the portion of subjects provided with hearing aids. At this degree the hearing loss is considered as a moderate hearing impairment (Martini, 1996) and the benefit of hearing aids is beyond dispute.

In addition to hearing loss, tinnitus is prevalent in noise-induced hearing impairment. *Paper C* also describes the portion of subjects, not exposed to hazardous occupational noise, reporting tinnitus. The logistic regression shows an age-related increase of reported tinnitus. The analysis also shows a gender difference, with higher prevalence among male subjects, which was not present for hearing loss prevalence. The prevalence results for reported tinnitus are similar to previous studies in Sweden (Axelsson and Ringdahl, 1989), in Great Britain (Davis, 1995) and in Italy (Quaranta et al, 1996). Age-related increase in prevalence of tinnitus has also been reported in previous studies, but a gender difference has only been present in the Swedish populations.

For both hearing loss and tinnitus the prevalence results shown in *Paper C* are probably underestimated if a general population including occupationally noise-exposed subjects are considered. In table 1 the difference in prevalence of HTL≤25 dB HL at 6 kHz between the two groups exposed to occupational noise and the reference data from *Paper B* is shown. According to the Swedish Work Environment Authority (2002b) more than a fifth of the employed population in Sweden are exposed to noise levels that prevent them from speech communication with normal vocal effort at least one fourth of the working time. If these exposed subjects had been included in the population under study the prevalence of hearing loss based on pure-tone average would probably increase. Thus, the actual need for rehabilitation is probably also somewhat larger than described in *Paper C*.

It was shown that by including the frequency 3 kHz in the pure-tone average the validity was enhanced. This result supports the use of M5 instead of M4 when evaluating HTL average on an individual basis. However, the contribution from the frequency 3 kHz was moderate when evaluating prevalence data. This gives the opportunity to compare M4 prevalence results to M5 prevalence results, using a linear transformation as described.

3.4.4 Paper D

The tympanometric results are similar to previous studies on normal-hearing populations. Distribution and median values of both middle ear pressure and middle ear compliance are similar to data from Hall III and Chandler (1994), Margolis and Heller (1987), Hall (1979), Jerger et al (1972), Brooks (1971), Burke et al (1970), Bicknell and Morgan (1968), and Feldman (1967), even if the skewness of the middle ear compliance distribution was larger and the middle ear pressure median was slightly more negative in the present study. No statistically significant effects from age, gender or ear side were present on middle ear pressure or middle ear compliance. Previous studies (Jerger et al, 1972) have suggested that age and gender should be taken into consideration. However, from the results presented in *Paper D* it is concluded that age and gender are not of interest in the clinical assessment of adult patients.

The prevalence of SOAEs in the present study is lower than previously found on normal-hearing populations (Moulin et al, 1993; Talmadge et al, 1993; Stover and Norton, 1993; Burns et al, 1992; Probst et al, 1991; Kemp et al, 1990; Martin et al, 1990; Lind and Randa, 1990; Bilger et al, 1990). From *Paper C* the results show that the overall prevalence of normal-hearing subjects (M4 BE≤20 dB HL) was 79% for female and 75% for male subjects in the population under study. If only subjects with HTL≤20 dB HL for both ears at 0.25 kHz to 8 kHz were included, the prevalence of subjects with SOAE in at least one ear increased to 48%, corresponding well to previous studies.

No age effect was present for SOAEs in the population under study. In previous studies on normal-hearing subjects, a reduced prevalence was shown for subjects above the age of 50-60 years (Probst et al, 1991; Stover and Norton, 1993). It has also been shown that the number of SOAEs per emitting ear decreased with increasing age. Since the presence of SOAE is associated with low HTL for the emitting frequency (Probst et al, 1987) and the results from *Paper C* show increasing prevalence of hearing loss with increasing age, an age-related prevalence would have been expected in the present study. However, most SOAEs were recorded in the frequency range 1-2 kHz, which is not much affected by high frequency hearing loss, but also at frequencies from 400 Hz to 9 kHz. It is possible that even with a high frequency loss, or poor pure-tone average, regions of the cochlea with functioning outer hair cells are producing SOAEs. The age and gender distribution of subjects with and without SOAE is shown in figure 1. The prevalence in the six age groups for male and female subjects does not show any statistically significant age-related differences using Chi^2-test. However, the prevalence among female subjects was significantly higher statistically, than among male subjects ($p<0.01$).

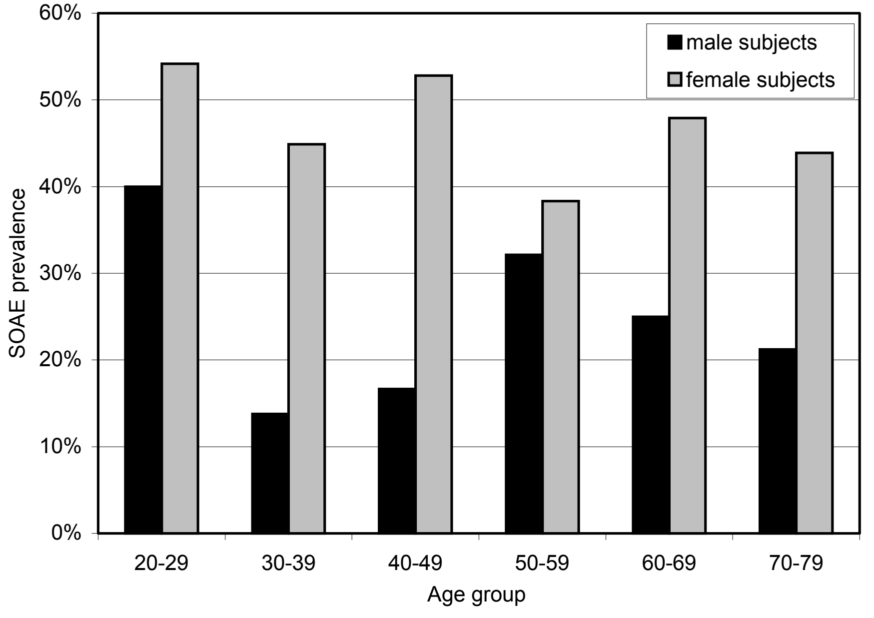

Figure 1. *SOAE prevalence for female and male subjects in different age groups.*

Since TEOAE and DPOAE results are dependent on stimulus levels and methods for signal analysis, the reference data presented in *Paper D* are not directly applicable to other population based studies on OAE. However, the effects from gender, age and middle ear compliance on OAE signal level are general. To distinguish between the age-related shift in HTL from possible age-related shift in OAE, HTL was introduced as covariate in the analyses. After adjusting for the HTL, both gender and age effects were present. While the increasing age-related shift in HTL was largest in subjects older than 50 years, the largest age-related shift in TEOAE and DPOAE signal levels occurred at about 30 years of age.

Paper D shows a relationship between OAE signal level and middle ear compliance. High middle ear compliance results in lower TEOAE and DPOAE signal level. This effect is probably caused by energy loss in the tympanic membrane during the signal and response transmission. This result suggests that middle ear compliance should be considered when measuring TEOAE and DPOAE.

Both for TEOAE and DPOAE the stimulus level affects the OAE signal level. The lack of standardised parameter values makes comparisons between different studies complicated and potentially inaccurate. The default stimulus levels used in *Paper D* might not be optimal. Studies (Ravazzani et al, 1996; Whitehead et al, 1994; Grandori and Ravazzani, 1993) have shown that a higher stimulus level for TEOAE measurements in derived non-linear mode might be preferable. The relatively low stimulus level used for TEOAE measurements in the present study might result in lower prevalence of true positive recordings. For DPOAE measurements a level difference between the two stimuli might increase the DPOAE signal level, compared to equal level stimuli. This factor is not crucial when measuring normal-hearing subjects, but in subjects with sensorineural hearing loss the sensitivity of the DPOAE measurements might be reduced by using equal level stimuli (Whitehead et al, 1995).

To detect true positive OAE responses relevant signal-to-noise criteria must be used. For the equipment used in *Paper D* criteria were determined based on the distribution of recorded noise levels. An S/N ratio based on 5% risk to detect noise as OAE signal was used for the TEOAE recordings. For the DPOAE recordings the signal analysis determined a noise floor and a signal level. The DPOAE recordings were considered as true positive if the signal level exceeded the noise floor by 3 dB. Differences in results between different studies might also be due to different criteria for true positive OAE recordings.

3.4.5 In general

The studies described in *Papers B, C and D* are all based on the same subject selection. Only about one third of the selected population was included in the analyses. The main reason for the large number of dropouts was the low response rate to the invitation letter. Only about 45% of the invited subjects replied, but almost all of those were positive to participating. Additional dropout during the studies decreased the participation rate even more. In *Paper B* 32.4% of the invited subjects were included in the analysis. In *Paper C* the corresponding figure was 32.7% and in *Paper D* the figure was 27.3%. However, the dropouts were quite randomly distributed over age, with a slightly larger proportion of dropouts in the youngest age groups. In *Paper D* it is shown that the age distribution of the population under study did not differ significantly from the age distribution of the population in Sweden.

Primarily day-time examinations, no economic compensation and less concern about one's health are possible explanations for the lower response rate among young subjects compared to older. A possible bias of the results may be an underrepresentation of hearing-impaired subjects, since they already have a personal relation to the audiological clinic and are well aware of their hearing status. On the other hand it might as well be the opposite case with an overrepresentation of hearing-impaired subjects, since they might be more interested in having their hearing tested than the general population.

Even if there were more dropouts among the youngest subjects, the variance in the HTL results in *Paper B* was small in these groups. The purpose of the reference data is for evaluation of noise-induced hearing loss. Since that effect is generally very small in the youngest age groups and the application of the results are probably of most significance in the older age groups, a possible lower reliability of these results is not crucial.

One critical factor when conducting hearing measurements is the background noise level. To ensure reliable audiometric results, insert earphones was used. The measurements were conducted in a sound-attenuating booth either in one of three different clinics in the province, or in a mobile unit. The maximum permissible noise levels and measured noise levels are described in *Paper B*, table 1. The results of the measurements described did not exceed the limit values for ambient noise according to ISO 8253-1 (International Organization for Standardization, 1989).

The degree of exposure to hazardous occupational noise was estimated by the subject through a questionnaire (*Appendix I*). The estimation was based on subjective assessment of the ability to communicate with another person. This might cause some bias in the selection of the population. People working in loud noise might estimate the ability to communicate differently compared to people not working in loud noise. A person who does not normally work in noise might, for the same noise level, have a subjective speech interference level 20 dB lower than a person who is accustomed to working in noise (Smith et al, 2000). Hearing impaired subjects could also misjudge the noise level because of larger than normal masking effects in loud noise. However, similar noise level estimations have been used in previous studies (Smith et al, 2000).

3.4.6 Practical application of results

To prevent occupational noise-induced hearing loss in Sweden, there are regulations on noise exposure. If the limit values of sound pressure levels are exceeded, action should be taken. In addition to actions to reduce the exposure, information regarding the noise exposure and its hazard, and provision of hearing protectors, workers' hearing should be examined. The prophylactic hearing investigations in Sweden are performed by occupational health care centres. If results from hearing investigations in occupational health care centres are administrated well, this gives an opportunity to evaluate general changes in specific working sites, but also in more general terms for different occupational domains. In the province of Östergötland, Sweden, a majority of the occupational hearing investigations are stored in a data base, which has been in use since the early 1970s. It now consists of over 163 000 audiograms and gives the opportunity to evaluate trends and changes in HTL among employees in the province of Östergötland. The information that can be extracted, the results of *Paper A*, is important for the individual employee, but also for the employer and the authorities.

Both in large scale studies and in individual evaluation of the hearing status, relevant reference data, as described in *Paper B*, are crucial. To be able to distinguish the impact from occupational noise from normal threshold shift, related to for example age, reference data are necessary in both scientific applications and, even more requested, in occupational health care. In occupational hearing conservation programs the ability to relate the results of hearing measurements to proper reference data provides the opportunity both to take action on an individual basis and to assess the occupational environment and the overall quality of the hearing conservation program.

In *Paper B* reference data of HTLs are presented. In addition to HTL data, classification of hearing loss is used to determine the need of hearing conservation actions or rehabilitation. For this purpose, age- and gender-separated prevalence data of different degree of hearing loss are needed as reference. The results presented in *Paper C* provide occupational health care centres, audiological clinics and authorities with epidemiological information regarding hearing loss, tinnitus and estimated need for rehabilitation.

The tympanometric reference data presented in *Paper D* is a contribution of large scale population data to the clinical evaluation of middle ear function. The OAE measurements are at this time mainly used in research or in neonatal screening. With knowledge of the methods and the interpretation of the results OAE measurements might be a relevant tool in clinical situations and in the detection of early noise-induced hearing loss. For this purpose experience from large scale population studies are relevant. The knowledge about influences from gender, age and other variables, such as middle ear compliance, is important when introducing OAE methods. The results from *Paper D* contribute to this knowledge and the possible introduction of OAE measurements as a test method to be used in occupational health care.

3.5 Conclusions

There was an improvement in HTL from the 1970s and 1980s into the 1990s in subjects from two occupational environments: mechanical industries and wood processing industries. However, the HTLs were still poorer than reference data for a population that had not been exposed to occupational noise.

A Swedish reference data base of HTLs for an otologically unscreened, non-occupationally noise-exposed population has been established according to specifications in ISO 1999 (International Organization for Standardization, 1990). It provides the basis for relevant evaluation of the auditory function in occupationally noise-exposed female and male subjects in the age span from 20 to 80 years. A mathematical model describing the age-related hearing threshold deterioration is presented and the influence from age, gender and ear side on HTLs has been determined.

The present state of hearing loss and prevalence of tinnitus has been determined for a non-occupationally noise-exposed population. The results and the influence from age, gender and ear side on the results have been compared to similar populations outside Sweden and provide a conservative indication of the need for resources in the healthcare system.

Prevalence data and mean signal levels of SOAEs, TEOAEs and DPOAEs are presented. Effects from age, gender, ear side and middle ear status on the emission levels were present. The results suggest that OAE measurements are less efficient if the middle ear compliance is high.

Reference data for middle ear pressure and middle ear compliance show similar results to previous studies on normal-hearing subjects.

This dissertation stresses the need for continuous monitoring and supervision of HTLs in order to avoid noise-induced hearing loss and maintain a minimally injurious working environment with regard to noise exposure. It also provides important instruments, in terms of reference data, for proper assessment of the auditory function among people exposed to hazardous noise.

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Appendix I

Questionnaire (translation from the Swedish original)

I

Universitetssjukhuset
i Linköping

Examination of hearing of the Swedish population

Please fill in and return this at the examination

We ask you to answer this questionnaire in order to obtain complementary information about your hearing and factors that might have affected it.

The first section of the questionnaire contains a form for personal data and questions regarding hearing, hearing-related diseases and medication. The second section contains questions regarding noise exposure. In the letter part we ask questions about military service and leisure noise and finally questions about your work environment today and previously.

You should answer the questions by putting a cross in the square or the squares that best correspond to your opinion. If there is a line for the answer, you should use it to write the answer. If you have any questions or are uncertain of anything you will have the opportunity to ask questions at the examination. You can add your own comments at the end of each section.

All data will be held in strictest confidence.

Magnus Johansson | Phone: 013 - 22 12 94
Dept of Audiology, Linköping University Hospital | Fax: 013 - 12 51 42
581 85 Linköping | E-mail: magjo@inr.liu.se

Personal data

Personal number ___ ___ ___ ___ ___ ___ – ___ ___ ___ ___

First name ____

Surname ____

Address ____

C/o ____

Postal code ___ ___ ___ ___ ___

City ____

Phone daytime __________ – ____________________________

Phone evening __________ – ____________________________

Cellphone __________ – ____________________________

Gender
☐ Female
☐ Male

Right- or lefthanded?
☐ Right
☐ Left

Hearing

Have you previously had any kind of hearing examination?

- ☐ Yes
- ☐ No
- ☐ Don't know

If your answer was Yes, what year? ______________________

Do you consider that you have poor hearing?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ No

Do you use hearing aids?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ No

Do you use any other kind of technical hearing equipment?

- ☐ Yes
- ☐ No

If your answer was Yes, what kind of aid do you use? ______________________

Do you consider it difficult to hear what others are saying when you have a lot of people around you?

- ☐ Yes
- ☐ No

Do you have permanent tinnitus (Permanent sounds in the ear, like pure-tones or noise)?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ No

If your answer was Yes, to what extent are you bothered by your tinnitus?

- ☐ Very bothered
- ☐ Quite bothered
- ☐ A bit bothered
- ☐ Not bothered at all

Do you have periodically recurrent tinnitus (Spontaneous sounds in the ear, like pure-tones or noise, that last for more than five minutes. Not temporary sounds connected with alcohol consumption or very loud sound exposure)

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ No

If your answer was Yes, to what extent are you bothered by your tinnitus?

- ☐ Very bothered
- ☐ Quite bothered
- ☐ A bit bothered
- ☐ Not bothered at all

Do you consider yourself oversensitive to noise?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ No

Do/did any close relative have hearing problems before the age of 65?

- ☐ Yes, my mother
- ☐ Yes, my father
- ☐ Yes, my sister
- ☐ Yes, my brother
- ☐ Yes, my half-sister
- ☐ Yes, my half-brother
- ☐ Yes, my grandmother
- ☐ Yes, my grandfather
- ☐ Yes, ________________
- ☐ No
- ☐ Don’t know

Comments: ____

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Ear diseases

Have you had an inflammation in your ear (otitis) as a child (before the age of 15 years)?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ Yes, but I don't know on which ear
- ☐ No
- ☐ Don't know

Have you ever had an inflammation in your ear (otitis) as an adult?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ Yes, but I don't know on which ear
- ☐ No
- ☐ Don't know

Do you have a chronic inflammation in your ear (chronic otitis)?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ Yes, but I don't know on which ear
- ☐ No
- ☐ Don't know

Comments: ____

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Ear surgery

Do you have or have you ever had a plastic tube surgically placed in your ear (tympanostomy)?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ Yes, but I don't know on which ear
- ☐ No
- ☐ Don't know

Have you ever had a middle ear operation?

- ☐ Yes, on both ears
- ☐ Yes, on the left ear
- ☐ Yes, on the right ear
- ☐ Yes, but I don't know on which ear
- ☐ No
- ☐ Don't know

Comments: ____

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Other diseases

Do you have diagnosed migraine?	☐ Yes ☐ No
Have you repeatedly experienced unconsciousness (ischemic attacks)?	☐ Yes ☐ No
Have you ever had a stroke?	☐ Yes ☐ No
Do you have diagnosed epilepsy?	☐ Yes ☐ No
Have you ever had meningitis?	☐ Yes ☐ No
Have you ever had encephalitis?	☐ Yes ☐ No
Have you ever had head trauma that has caused unconsciousness or hospitalisation?	☐ Yes ☐ No
Are you regularly affected by dizziness or disturbances of balance?	☐ Yes ☐ No
Do you have ”White fingers” (Raynaud’s syndrome)?	☐ Yes ☐ No

Comments: ____

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Medication

Are you currently using any anti-inflammatory or anti-rheumatic medicine?	☐ Yes ☐ No
If your answer was Yes, mark the medicine with a cross and state the approximate dose:	☐ Albyl dose: _____ ☐ Bamyl dose: _____ ☐ Magnecyl dose: _____ ☐ Voltaren dose: _____ ☐ Other: ___________ dose: _____ ☐ Don't know
Do you receive any medical treatment, preventive or as rehabilitation, for malaria at the moment?	☐ Yes ☐ No
If your answer was Yes, mark the medicine with a cross:	☐ Quinine ☐ Chloroquine phosphate ☐ Other: _______________ ☐ Don't know
Have you ever had medical treatment for a serious infection or a serious burn?	☐ Yes ☐ No
If your answer was Yes, mark the medicine with a cross:	☐ Gentamycin ☐ Kanamycin ☐ Streptomycin ☐ Other: _______________ ☐ Don't know
Have you ever had medical treatment for any kind of cancer?	☐ Yes ☐ No
If your answer was Yes, mark the medicine with a cross:	☐ Cisplatin ☐ Paraplatin ☐ Other: _______________ ☐ Don't know

Comments: ____

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Noise during the military service

Have you done any military service?

- ☐ Yes
- ☐ No

If your answer was Yes:

For how long time? __________ months

What kind of weapon did you use during shooting practice, if any?

- ☐ Firearms
- ☐ Other ________________

Did you fire with your right or with your left hand?

- ☐ Right
- ☐ Left

Did you use hearing protectors during shooting practice?

- ☐ Yes, at all occasions
- ☐ Yes, sometimes
- ☐ No, never

If your answer was Yes, what kind of hearing protectors did you use?

- ☐ Foam earplugs
- ☐ Other earplugs
- ☐ Earmuffs
- ☐ Other: ________________

Comments: ____

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Leisure noise

Are you or have you ever engaged in hunting or sport shooting?	☐ Yes ☐ No

If your answer was Yes:

What kind of weapon do/did you use?	☐ Pistol ☐ Rifle ☐ Other: ______________
Do/did you fire with your right or your left hand?	☐ Right ☐ Left
Estimate how many rounds you have fired without using hearing protectors:	☐ Less than 10 rounds ☐ 10 to 100 rounds ☐ 100 to 1000 rounds ☐ More than 1000 rounds
Estimate how many rounds you have fired all together when you have been using hearing protectors:	☐ Less than 10 rounds ☐ 10 to 100 rounds ☐ 100 to 1000 rounds ☐ More than 1000 rounds
What kind of hearing protectors have you used, if you have been using hearing protectors while shooting?	☐ Foam earplugs ☐ Other earplugs ☐ Earmuffs ☐ Other: ______________

Do you go to concerts, discos or similar activities?	☐ Yes, several times per month ☐ Yes, but not more than once a month ☐ No, never

If your answer was Yes:

Do you use hearing protectors?	☐ Yes, at all occasions ☐ Yes, sometimes ☐ No, never
If your answer was Yes, what kind of hearing protectors do you use?	☐ Foam earplugs ☐ Other earplugs ☐ Other: _______________
Do you use a freestyle or any other music equipment with headphones?	☐ Yes, almost daily ☐ Yes, several times per month ☐ Yes, but not more than once a month ☐ No, never
Do you listen to music while you are exercising?	☐ Yes, almost daily ☐ Yes, several times per month ☐ Yes, but not more than once a month ☐ No, never

Do you play or have you ever played any musical instrument?	☐ Yes, I'm playing now ☐ Yes, I've played previously ☐ No

If your answer was Yes:

What instrument/s?	______________________ ______________________
How often do/did you play?	☐ Almost daily ☐ Several times per month ☐ Not more than once a month
Do/did you play in an orchestra, a rock band or some similar type group?	☐ Yes ☐ No
Do/did you use hearing protectors?	☐ Yes, at all occasions ☐ Yes, sometimes ☐ No, never
If your answer was Yes, what kind of hearing protectors?	☐ Foam earplugs ☐ Other earplugs ☐ Other: ______________

Are you regularly exposed to noise during your leisure time for any other reason, for example motor sport, motor driven tools, power saw or power lawn mower?	☐ Yes, almost daily ☐ Yes, several times per month ☐ Yes, but not more than once a month ☐ No, never

If your answer was Yes:

From what kind of noise source?	______________________
Do you use hearing protectors at these occasions?	☐ Yes, at all occasions ☐ Yes, sometimes ☐ No, never
If your answer was Yes, what kind of hearing protectors do you use?	☐ Foam earplugs ☐ Other earplugs ☐ Earmuffs ☐ Other: ______________

Comments: ____

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Noise during work

What is your present occupational situation?

- ☐ Full-time job, part-time job, spare-time job, or unemployment program
- ☐ Unemployed
- ☐ Retired
- ☐ Student
- ☐ Other: ______________

If you have two positions today, answer all questions regarding one of the jobs first, and then the questions about the other job at page 15. If you don't have any position at present, continue with the questions at page 17 about previous works.

Profession 1 ____

For how long have you been employed? years and_____ months

Assignment: ____

What are your regular hours of working?

- ☐ 0-20%
- ☐ 21-40%
- ☐ 41-60%
- ☐ 61-80%
- ☐ 81-100%

Do you consider your working environment noisy?

- ☐ Yes, in most cases
- ☐ Yes, sometimes
- ☐ No, never

If your answer to the question was Yes, in what kind of noise do you work?

- ☐ Constant noise
- ☐ Noise now and then
- ☐ Sudden, loud sound

If you are exposed to noise at work do you use hearing protectors during that time?	☐ Yes, always ☐ Yes, sometimes ☐ No, never
If your answer was Yes, what kind of hearing protectors do you use?	☐ Foam earplugs ☐ Other earplugs ☐ Earmuffs ☐ Other: ______________
Are you able to have a conversation with a colleague at a distance of one meter (Mark the alternative that agrees most even if you usually do not converse during work. This is for estimation of the noise level at your workplace)?	☐ Yes, with normal voice ☐ Yes, with raised voice ☐ Yes, if I shout ☐ No, not at all
Do you handle solvents at work?	☐ Yes ☐ No
If your answer was Yes, what kind of solvent do you handle?	☐ Styrene ☐ Toluene ☐ Other: ______________

Comments: ____

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Profession 2 ____

For how long have you been employed? years and_____ months

Assignment: ____

What are your regular hours of working?

- ☐ 0-20%
- ☐ 21-40%
- ☐ 41-60%
- ☐ 61-80%
- ☐ 81-100%

Do you consider your working environment noisy?

- ☐ Yes, in most cases
- ☐ Yes, sometimes
- ☐ No, never

If your answer to the question was Yes, in what kind of noise do you work?

- ☐ Constant noise
- ☐ Noise now and then
- ☐ Sudden, loud sound

If you are exposed to noise at work do you use hearing protectors during that time?

- ☐ Yes, always
- ☐ Yes, sometimes
- ☐ No, never

If your answer was Yes, what kind of hearing protectors do you use?

- ☐ Foam earplugs
- ☐ Other earplugs
- ☐ Earmuffs
- ☐ Other: ______________

Are you able to have a conversation with a colleague at a distance of one meter (Mark the alternative that agrees most even if you usually do not converse during work. This is for estimation of the noise level at your workplace)?	☐	Yes, with normal voice
	☐	Yes, with raised voice
	☐	Yes, if I shout
	☐	No, not at all
Do you handle solvents at work?	☐	Yes
	☐	No
If your answer was Yes, what kind of solvent do you handle?	☐	Styrene
	☐	Toluene
	☐	Other: ________________

Comments: ____

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The following questions deal with your previous positions. If you have had more than four positions choose those four that might have had the greatest impact on your hearing.

Previous profession 1 ____

For how long were you employed?____ years and _____months

Time of employment __________ until year __________

Assignment ____

Previous profession 2 ____

For how long were you employed?____ years and _____months

Time of employment __________ until year __________

Assignment ____

Previous profession 3 ____

For how long were you employed?____ years and _____months

Time of employment __________ until year __________

Assignment ____

Previous profession 4 ____

For how long were you employed?____ years and _____months

Time of employment __________ until year __________

Assignment ____

		Prof. 1	Prof. 2	Prof. 3	Prof. 4
What were your regular hours of working?	0-20%	☐	☐	☐	☐
	21-40%	☐	☐	☐	☐
	41-60%	☐	☐	☐	☐
	61-80%	☐	☐	☐	☐
	81-100%	☐	☐	☐	☐
Did you consider your working environment noisy?	Yes, in most cases	☐	☐	☐	☐
	Yes, sometimes	☐	☐	☐	☐
	No, never	☐	☐	☐	☐
If your answer to the question was Yes, in what kind of noise did you work?	Constant noise	☐	☐	☐	☐
	Noise now and then	☐	☐	☐	☐
	Sudden, loud sounds	☐	☐	☐	☐
If you were exposed to noise at work did you use hearing protectors during that time?	Yes, always	☐	☐	☐	☐
	Yes, sometimes	☐	☐	☐	☐
	No, never	☐	☐	☐	☐
If your answer was Yes, what kind of hearing protectors did you use?	Foam earplugs	☐	☐	☐	☐
	Other earplugs	☐	☐	☐	☐
	Earmuffs	☐	☐	☐	☐
	Other:	______	______	______	______
Were you able to have a conversation with a colleague at a distance of one meter (Mark the alternative that agrees most even if you usually do did not converse during work. This is for estimation of the noise level at your workplace)?	Yes, with normal voice	☐	☐	☐	☐
	Yes, with raised voice	☐	☐	☐	☐
	Yes, if I shouted	☐	☐	☐	☐
	No, not at all	☐	☐	☐	☐
Did you handle solvents at work?	Yes	☐	☐	☐	☐
	No	☐	☐	☐	☐
If your answer was Yes, what kind of solvent did you handle?	Styrene	☐	☐	☐	☐
	Toluene	☐	☐	☐	☐
	Other:	______	______	______	______

Comments: ____

Thank you for your participation!

Appendix II

Hearing threshold levels for otologically unscreened, non-occupationally noise-exposed female and male subjects aged from 20 to 79 years.

II

Also available at:

http://www.av.se/publikationer/bocker/fysiskt/h293.shtm

Female subjects
10th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	-0.8	-1.2	-1.3	-1.5	-1.2	-1.9	-3.0	-4.2	-5.7	-6.7
21 years	-0.8	-1.2	-1.3	-1.4	-1.2	-1.8	-3.0	-4.2	-5.7	-6.6
22 years	-0.8	-1.2	-1.2	-1.4	-1.2	-1.7	-2.9	-4.1	-5.6	-6.5
23 years	-0.7	-1.2	-1.2	-1.3	-1.2	-1.7	-2.9	-4.1	-5.6	-6.4
24 years	-0.7	-1.2	-1.2	-1.3	-1.2	-1.6	-2.8	-4.1	-5.5	-6.3
25 years	-0.6	-1.1	-1.1	-1.2	-1.2	-1.5	-2.8	-4.0	-5.4	-6.2
26 years	-0.6	-1.1	-1.1	-1.2	-1.2	-1.5	-2.7	-4.0	-5.4	-6.1
27 years	-0.5	-1.1	-1.1	-1.1	-1.2	-1.4	-2.6	-3.9	-5.3	-6.0
28 years	-0.4	-1.1	-1.0	-1.1	-1.2	-1.3	-2.6	-3.9	-5.2	-5.8
29 years	-0.4	-1.0	-1.0	-1.0	-1.1	-1.2	-2.5	-3.8	-5.2	-5.7
30 years	-0.3	-1.0	-0.9	-0.9	-1.1	-1.1	-2.4	-3.7	-5.1	-5.5
31 years	-0.2	-1.0	-0.9	-0.9	-1.1	-1.0	-2.3	-3.7	-5.0	-5.3
32 years	-0.1	-0.9	-0.8	-0.8	-1.1	-0.9	-2.2	-3.6	-4.9	-5.2
33 years	0.0	-0.9	-0.8	-0.7	-1.1	-0.8	-2.1	-3.5	-4.8	-5.0
34 years	0.1	-0.8	-0.7	-0.6	-1.1	-0.6	-2.0	-3.4	-4.7	-4.8
35 years	0.2	-0.8	-0.6	-0.5	-1.1	-0.5	-1.8	-3.3	-4.5	-4.5
36 years	0.4	-0.7	-0.6	-0.4	-1.0	-0.4	-1.7	-3.2	-4.4	-4.3
37 years	0.5	-0.7	-0.5	-0.3	-1.0	-0.2	-1.6	-3.1	-4.2	-4.0
38 years	0.7	-0.6	-0.4	-0.2	-1.0	-0.1	-1.4	-2.9	-4.1	-3.8
39 years	0.8	-0.5	-0.3	0.0	-0.9	0.1	-1.2	-2.8	-3.9	-3.5
40 years	1.0	-0.4	-0.2	0.1	-0.9	0.3	-1.1	-2.6	-3.7	-3.2
41 years	1.2	-0.3	-0.1	0.2	-0.9	0.4	-0.9	-2.5	-3.5	-2.8
42 years	1.4	-0.2	0.0	0.4	-0.8	0.6	-0.7	-2.3	-3.3	-2.5
43 years	1.6	-0.1	0.2	0.5	-0.8	0.8	-0.5	-2.1	-3.1	-2.1
44 years	1.8	0.0	0.3	0.7	-0.7	1.0	-0.3	-1.9	-2.8	-1.7
45 years	2.1	0.2	0.4	0.9	-0.6	1.3	0.0	-1.6	-2.6	-1.3
46 years	2.3	0.3	0.6	1.1	-0.6	1.5	0.2	-1.4	-2.3	-0.8
47 years	2.6	0.5	0.8	1.3	-0.5	1.7	0.5	-1.1	-2.0	-0.3
48 years	2.9	0.6	0.9	1.5	-0.4	2.0	0.8	-0.8	-1.7	0.2
49 years	3.2	0.8	1.1	1.7	-0.3	2.2	1.1	-0.5	-1.3	0.7
50 years	3.5	1.0	1.3	2.0	-0.2	2.5	1.4	-0.1	-0.9	1.3
51 years	3.8	1.3	1.5	2.2	-0.1	2.8	1.8	0.2	-0.5	1.9
52 years	4.1	1.5	1.7	2.5	0.1	3.1	2.1	0.6	-0.1	2.5
53 years	4.5	1.8	2.0	2.7	0.2	3.4	2.5	1.1	0.4	3.2
54 years	4.9	2.0	2.2	3.0	0.4	3.7	2.9	1.5	0.9	3.9
55 years	5.2	2.3	2.5	3.3	0.6	4.1	3.3	2.0	1.4	4.7
56 years	5.6	2.6	2.8	3.6	0.8	4.4	3.8	2.5	1.9	5.5
57 years	6.0	3.0	3.1	3.9	1.0	4.8	4.2	3.1	2.5	6.3
58 years	6.4	3.3	3.4	4.3	1.3	5.2	4.7	3.7	3.1	7.2
59 years	6.8	3.7	3.7	4.6	1.5	5.5	5.2	4.4	3.8	8.1
60 years	7.2	4.1	4.0	5.0	1.8	5.9	5.8	5.0	4.5	9.1
61 years	7.6	4.5	4.4	5.4	2.2	6.4	6.3	5.8	5.3	10.1
62 years	8.0	4.9	4.7	5.8	2.5	6.8	6.9	6.5	6.1	11.1
63 years	8.5	5.4	5.1	6.2	2.9	7.2	7.5	7.3	6.9	12.2
64 years	8.9	5.8	5.5	6.6	3.2	7.7	8.2	8.2	7.8	13.4
65 years	9.3	6.3	5.9	7.0	3.7	8.1	8.8	9.1	8.7	14.5
66 years	9.7	6.8	6.3	7.4	4.1	8.6	9.5	10.0	9.6	15.8
67 years	10.0	7.2	6.7	7.8	4.6	9.1	10.2	10.9	10.6	17.0
68 years	10.4	7.7	7.1	8.3	5.0	9.6	10.9	11.9	11.7	18.3
69 years	10.8	8.2	7.5	8.7	5.5	10.1	11.6	13.0	12.8	19.7
70 years	11.1	8.7	8.0	9.2	6.0	10.6	12.3	14.1	13.9	21.1
71 years	11.5	9.2	8.4	9.7	6.6	11.1	13.1	15.2	15.1	22.5
72 years	11.8	9.7	8.8	10.1	7.1	11.6	13.9	16.3	16.3	24.0
73 years	12.1	10.2	9.3	10.6	7.6	12.2	14.7	17.4	17.5	25.5
74 years	12.4	10.6	9.7	11.1	8.2	12.7	15.5	18.6	18.8	27.0
75 years	12.7	11.1	10.2	11.5	8.7	13.2	16.3	19.8	20.1	28.5
76 years	13.0	11.5	10.6	12.0	9.2	13.8	17.1	21.0	21.5	30.1
77 years	13.2	11.9	11.0	12.5	9.7	14.3	17.9	22.2	22.8	31.7
78 years	13.5	12.3	11.4	12.9	10.2	14.9	18.7	23.4	24.2	33.3
79 years	13.7	12.7	11.8	13.4	10.7	15.4	19.5	24.6	25.6	34.9

Female subjects
20th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	0.9	0.4	0.4	0.1	-0.6	-0.4	-1.3	-2.3	-3.7	-5.2
21 years	0.9	0.4	0.4	0.2	-0.6	-0.3	-1.2	-2.3	-3.7	-5.2
22 years	1.0	0.5	0.4	0.2	-0.5	-0.3	-1.2	-2.2	-3.6	-5.1
23 years	1.0	0.5	0.5	0.3	-0.5	-0.2	-1.1	-2.2	-3.5	-5.0
24 years	1.1	0.5	0.5	0.3	-0.5	-0.1	-1.1	-2.1	-3.5	-5.0
25 years	1.1	0.6	0.6	0.4	-0.5	0.0	-1.0	-2.1	-3.4	-4.9
26 years	1.2	0.6	0.6	0.4	-0.4	0.0	-0.9	-2.0	-3.3	-4.8
27 years	1.3	0.6	0.6	0.5	-0.4	0.1	-0.8	-2.0	-3.3	-4.7
28 years	1.4	0.7	0.7	0.6	-0.4	0.2	-0.7	-1.9	-3.2	-4.6
29 years	1.5	0.7	0.8	0.7	-0.3	0.3	-0.6	-1.8	-3.1	-4.5
30 years	1.6	0.8	0.8	0.7	-0.3	0.4	-0.5	-1.8	-3.0	-4.3
31 years	1.7	0.8	0.9	0.8	-0.2	0.5	-0.4	-1.7	-2.8	-4.2
32 years	1.8	0.9	0.9	0.9	-0.2	0.7	-0.3	-1.6	-2.7	-4.0
33 years	1.9	0.9	1.0	1.0	-0.1	0.8	-0.2	-1.5	-2.6	-3.9
34 years	2.0	1.0	1.1	1.1	-0.1	0.9	0.0	-1.3	-2.4	-3.7
35 years	2.2	1.1	1.2	1.2	0.0	1.1	0.1	-1.2	-2.3	-3.5
36 years	2.3	1.1	1.3	1.3	0.0	1.3	0.3	-1.1	-2.1	-3.3
37 years	2.5	1.2	1.4	1.5	0.1	1.4	0.4	-0.9	-1.9	-3.0
38 years	2.6	1.3	1.5	1.6	0.2	1.6	0.6	-0.8	-1.7	-2.7
39 years	2.8	1.4	1.6	1.8	0.3	1.8	0.8	-0.6	-1.5	-2.4
40 years	3.0	1.5	1.7	1.9	0.4	2.0	1.1	-0.4	-1.2	-2.1
41 years	3.2	1.7	1.9	2.1	0.5	2.2	1.3	-0.2	-1.0	-1.8
42 years	3.4	1.8	2.0	2.3	0.6	2.5	1.5	0.0	-0.7	-1.4
43 years	3.7	1.9	2.2	2.5	0.7	2.7	1.8	0.3	-0.4	-0.9
44 years	3.9	2.1	2.3	2.7	0.8	3.0	2.1	0.6	0.0	-0.5
45 years	4.2	2.2	2.5	2.9	1.0	3.3	2.4	0.8	0.3	0.0
46 years	4.5	2.4	2.7	3.1	1.1	3.6	2.7	1.2	0.7	0.6
47 years	4.8	2.6	2.9	3.3	1.3	3.9	3.1	1.5	1.1	1.2
48 years	5.1	2.8	3.1	3.6	1.5	4.2	3.4	1.9	1.6	1.8
49 years	5.4	3.0	3.3	3.9	1.7	4.6	3.8	2.3	2.1	2.5
50 years	5.7	3.3	3.6	4.2	1.9	4.9	4.2	2.7	2.6	3.3
51 years	6.1	3.5	3.8	4.5	2.1	5.3	4.7	3.2	3.2	4.1
52 years	6.5	3.8	4.1	4.8	2.4	5.7	5.1	3.6	3.8	5.0
53 years	6.8	4.1	4.4	5.1	2.6	6.1	5.6	4.2	4.4	5.9
54 years	7.2	4.4	4.7	5.5	2.9	6.6	6.2	4.7	5.1	6.9
55 years	7.6	4.7	5.0	5.8	3.2	7.1	6.7	5.4	5.8	8.0
56 years	8.0	5.0	5.3	6.2	3.5	7.5	7.3	6.0	6.6	9.2
57 years	8.5	5.4	5.7	6.6	3.9	8.1	7.9	6.7	7.5	10.4
58 years	8.9	5.7	6.0	7.0	4.2	8.6	8.5	7.4	8.3	11.8
59 years	9.4	6.1	6.4	7.5	4.6	9.1	9.2	8.2	9.3	13.2
60 years	9.8	6.5	6.8	7.9	5.0	9.7	9.9	9.0	10.3	14.6
61 years	10.3	7.0	7.2	8.4	5.5	10.3	10.6	9.9	11.3	16.2
62 years	10.7	7.4	7.6	8.9	6.0	10.9	11.4	10.8	12.4	17.8
63 years	11.2	7.9	8.1	9.4	6.5	11.5	12.1	11.8	13.6	19.5
64 years	11.7	8.3	8.5	9.9	7.0	12.1	12.9	12.8	14.8	21.3
65 years	12.1	8.8	9.0	10.4	7.5	12.8	13.8	13.8	16.0	23.2
66 years	12.6	9.3	9.4	10.9	8.1	13.4	14.6	14.9	17.3	25.1
67 years	13.0	9.8	9.9	11.5	8.7	14.1	15.5	16.0	18.7	27.1
68 years	13.5	10.3	10.4	12.0	9.3	14.8	16.3	17.1	20.1	29.1
69 years	13.9	10.8	10.9	12.6	9.9	15.5	17.2	18.3	21.5	31.2
70 years	14.4	11.4	11.4	13.1	10.6	16.1	18.2	19.5	23.0	33.3
71 years	14.8	11.9	11.9	13.7	11.3	16.8	19.1	20.7	24.5	35.4
72 years	15.2	12.4	12.4	14.2	12.0	17.5	20.0	22.0	26.0	37.6
73 years	15.6	12.9	12.9	14.8	12.7	18.2	20.9	23.2	27.6	39.7
74 years	16.0	13.5	13.4	15.4	13.4	18.9	21.9	24.5	29.1	41.9
75 years	16.4	14.0	13.9	15.9	14.2	19.6	22.8	25.7	30.7	44.0
76 years	16.7	14.5	14.4	16.5	14.9	20.3	23.7	27.0	32.3	46.1
77 years	17.1	15.0	14.9	17.0	15.7	21.0	24.6	28.2	33.9	48.2
78 years	17.4	15.4	15.4	17.6	16.4	21.7	25.6	29.4	35.4	50.2
79 years	17.7	15.9	15.9	18.1	17.2	22.4	26.4	30.7	37.0	52.2

Female subjects
30th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	2.5	2.0	1.9	1.7	1.0	1.3	0.3	-0.6	-1.8	-3.2
21 years	2.5	2.0	2.0	1.7	1.0	1.3	0.3	-0.6	-1.8	-3.1
22 years	2.6	2.0	2.0	1.8	1.0	1.4	0.4	-0.6	-1.7	-3.1
23 years	2.6	2.1	2.1	1.8	1.0	1.5	0.4	-0.6	-1.7	-3.0
24 years	2.7	2.1	2.1	1.8	1.1	1.6	0.5	-0.5	-1.6	-2.9
25 years	2.8	2.1	2.1	1.9	1.1	1.6	0.6	-0.5	-1.6	-2.9
26 years	2.9	2.2	2.2	2.0	1.1	1.7	0.6	-0.4	-1.5	-2.8
27 years	2.9	2.2	2.2	2.0	1.1	1.8	0.7	-0.4	-1.4	-2.7
28 years	3.0	2.3	2.3	2.1	1.2	1.9	0.8	-0.3	-1.3	-2.6
29 years	3.1	2.3	2.4	2.2	1.2	2.0	0.9	-0.3	-1.2	-2.5
30 years	3.2	2.4	2.4	2.2	1.2	2.1	1.0	-0.2	-1.1	-2.3
31 years	3.3	2.4	2.5	2.3	1.3	2.3	1.1	-0.1	-1.0	-2.2
32 years	3.5	2.5	2.6	2.4	1.3	2.4	1.2	-0.1	-0.9	-2.0
33 years	3.6	2.6	2.6	2.5	1.4	2.5	1.3	0.0	-0.8	-1.8
34 years	3.7	2.6	2.7	2.6	1.4	2.7	1.5	0.1	-0.6	-1.6
35 years	3.9	2.7	2.8	2.7	1.5	2.9	1.6	0.2	-0.4	-1.4
36 years	4.0	2.8	2.9	2.9	1.5	3.0	1.8	0.4	-0.3	-1.2
37 years	4.2	2.9	3.0	3.0	1.6	3.2	2.0	0.5	-0.1	-0.9
38 years	4.4	3.0	3.2	3.1	1.7	3.4	2.2	0.7	0.2	-0.6
39 years	4.6	3.1	3.3	3.3	1.8	3.7	2.4	0.8	0.4	-0.3
40 years	4.8	3.2	3.4	3.4	1.9	3.9	2.6	1.0	0.7	0.0
41 years	5.0	3.3	3.6	3.6	2.0	4.1	2.9	1.2	0.9	0.4
42 years	5.2	3.5	3.7	3.8	2.1	4.4	3.1	1.5	1.3	0.8
43 years	5.4	3.6	3.9	4.0	2.2	4.7	3.4	1.7	1.6	1.3
44 years	5.7	3.8	4.1	4.2	2.4	5.0	3.7	2.0	2.0	1.8
45 years	6.0	3.9	4.2	4.5	2.5	5.3	4.1	2.3	2.4	2.4
46 years	6.3	4.1	4.4	4.7	2.7	5.6	4.5	2.7	2.8	3.0
47 years	6.6	4.3	4.7	5.0	2.9	6.0	4.9	3.0	3.3	3.7
48 years	6.9	4.5	4.9	5.3	3.1	6.4	5.3	3.4	3.9	4.4
49 years	7.2	4.8	5.1	5.5	3.3	6.8	5.8	3.9	4.4	5.2
50 years	7.6	5.0	5.4	5.9	3.6	7.2	6.2	4.4	5.0	6.1
51 years	7.9	5.3	5.7	6.2	3.9	7.7	6.8	4.9	5.7	7.0
52 years	8.3	5.6	6.0	6.6	4.2	8.1	7.3	5.5	6.4	8.0
53 years	8.7	5.9	6.3	6.9	4.5	8.6	7.9	6.2	7.2	9.2
54 years	9.1	6.2	6.6	7.3	4.8	9.1	8.6	6.9	8.1	10.3
55 years	9.5	6.5	6.9	7.7	5.2	9.7	9.3	7.6	9.0	11.6
56 years	10.0	6.9	7.3	8.2	5.6	10.2	10.0	8.4	9.9	13.0
57 years	10.4	7.2	7.7	8.6	6.1	10.8	10.7	9.3	11.0	14.4
58 years	10.9	7.6	8.1	9.1	6.5	11.4	11.5	10.2	12.1	16.0
59 years	11.4	8.0	8.5	9.6	7.1	12.1	12.4	11.2	13.2	17.6
60 years	11.9	8.5	8.9	10.1	7.6	12.7	13.2	12.3	14.5	19.4
61 years	12.4	8.9	9.4	10.7	8.2	13.4	14.1	13.4	15.7	21.2
62 years	12.9	9.4	9.8	11.2	8.8	14.1	15.1	14.6	17.1	23.1
63 years	13.4	9.9	10.3	11.8	9.5	14.8	16.1	15.9	18.5	25.1
64 years	13.9	10.4	10.8	12.4	10.2	15.5	17.1	17.2	20.0	27.2
65 years	14.4	10.9	11.3	13.0	10.9	16.3	18.1	18.5	21.6	29.3
66 years	14.9	11.4	11.8	13.7	11.7	17.0	19.1	19.9	23.2	31.5
67 years	15.5	12.0	12.4	14.3	12.5	17.8	20.2	21.4	24.8	33.7
68 years	16.0	12.6	12.9	14.9	13.3	18.6	21.3	22.8	26.5	36.0
69 years	16.5	13.1	13.5	15.6	14.2	19.4	22.4	24.3	28.2	38.2
70 years	17.0	13.7	14.1	16.3	15.1	20.2	23.5	25.9	29.9	40.5
71 years	17.5	14.3	14.6	16.9	16.0	21.0	24.6	27.4	31.7	42.8
72 years	18.0	14.9	15.2	17.6	16.9	21.8	25.8	28.9	33.4	45.1
73 years	18.5	15.5	15.8	18.3	17.9	22.5	26.9	30.4	35.2	47.3
74 years	19.0	16.1	16.4	19.0	18.8	23.3	27.9	31.9	37.0	49.5
75 years	19.5	16.7	17.0	19.6	19.8	24.1	29.0	33.4	38.7	51.7
76 years	19.9	17.3	17.5	20.3	20.7	24.9	30.1	34.9	40.4	53.8
77 years	20.4	17.9	18.1	20.9	21.6	25.6	31.1	36.2	42.1	55.8
78 years	20.8	18.4	18.7	21.6	22.6	26.4	32.1	37.6	43.8	57.8
79 years	21.2	19.0	19.3	22.2	23.5	27.1	33.1	38.9	45.4	59.6

Female subjects
40th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	4.1	3.6	3.4	3.1	2.6	2.7	2.0	1.2	0.1	-1.1
21 years	4.1	3.6	3.5	3.2	2.6	2.7	2.0	1.2	0.2	-1.1
22 years	4.2	3.6	3.5	3.2	2.6	2.8	2.0	1.2	0.2	-1.0
23 years	4.2	3.6	3.5	3.2	2.7	2.9	2.1	1.2	0.3	-0.9
24 years	4.3	3.7	3.6	3.3	2.7	2.9	2.1	1.3	0.3	-0.9
25 years	4.4	3.7	3.6	3.3	2.7	3.0	2.2	1.3	0.4	-0.8
26 years	4.5	3.8	3.7	3.4	2.7	3.1	2.3	1.4	0.5	-0.7
27 years	4.5	3.8	3.7	3.4	2.7	3.1	2.3	1.4	0.5	-0.6
28 years	4.6	3.8	3.7	3.5	2.8	3.2	2.4	1.5	0.6	-0.5
29 years	4.7	3.9	3.8	3.6	2.8	3.3	2.5	1.5	0.7	-0.4
30 years	4.8	4.0	3.9	3.6	2.8	3.4	2.6	1.6	0.8	-0.3
31 years	4.9	4.0	3.9	3.7	2.9	3.5	2.7	1.7	0.9	-0.1
32 years	5.1	4.1	4.0	3.8	2.9	3.7	2.8	1.7	1.1	0.0
33 years	5.2	4.1	4.1	3.9	3.0	3.8	2.9	1.8	1.2	0.2
34 years	5.3	4.2	4.2	4.0	3.0	4.0	3.1	1.9	1.4	0.4
35 years	5.5	4.3	4.3	4.1	3.1	4.1	3.2	2.1	1.6	0.6
36 years	5.6	4.4	4.3	4.2	3.1	4.3	3.4	2.2	1.7	0.9
37 years	5.8	4.5	4.5	4.3	3.2	4.5	3.6	2.3	2.0	1.2
38 years	6.0	4.6	4.6	4.4	3.3	4.7	3.8	2.5	2.2	1.5
39 years	6.2	4.7	4.7	4.6	3.4	4.9	4.0	2.7	2.5	1.8
40 years	6.4	4.8	4.8	4.7	3.5	5.1	4.3	2.9	2.7	2.2
41 years	6.6	5.0	5.0	4.9	3.6	5.4	4.5	3.1	3.1	2.7
42 years	6.8	5.1	5.1	5.1	3.7	5.7	4.8	3.4	3.4	3.1
43 years	7.1	5.2	5.3	5.3	3.9	6.0	5.1	3.6	3.8	3.7
44 years	7.3	5.4	5.5	5.5	4.0	6.3	5.5	4.0	4.2	4.2
45 years	7.6	5.6	5.7	5.8	4.2	6.7	5.8	4.3	4.7	4.9
46 years	7.9	5.8	5.9	6.0	4.4	7.1	6.3	4.7	5.2	5.6
47 years	8.2	6.0	6.1	6.3	4.6	7.5	6.7	5.1	5.7	6.4
48 years	8.5	6.2	6.3	6.6	4.8	7.9	7.2	5.6	6.3	7.2
49 years	8.8	6.4	6.6	6.9	5.1	8.4	7.7	6.1	7.0	8.2
50 years	9.2	6.7	6.9	7.2	5.4	8.9	8.2	6.7	7.7	9.2
51 years	9.5	6.9	7.2	7.6	5.7	9.4	8.8	7.3	8.4	10.3
52 years	9.9	7.2	7.5	8.0	6.0	9.9	9.5	8.0	9.3	11.5
53 years	10.3	7.5	7.8	8.4	6.4	10.5	10.2	8.7	10.2	12.9
54 years	10.7	7.9	8.2	8.8	6.8	11.2	10.9	9.5	11.1	14.3
55 years	11.2	8.2	8.5	9.3	7.2	11.8	11.7	10.4	12.2	15.8
56 years	11.6	8.6	8.9	9.8	7.7	12.5	12.5	11.3	13.3	17.4
57 years	12.1	8.9	9.3	10.3	8.2	13.3	13.4	12.4	14.5	19.2
58 years	12.6	9.4	9.8	10.8	8.8	14.0	14.3	13.5	15.7	21.0
59 years	13.0	9.8	10.2	11.4	9.4	14.8	15.3	14.6	17.1	23.0
60 years	13.6	10.2	10.7	12.0	10.0	15.7	16.3	15.9	18.5	25.0
61 years	14.1	10.7	11.2	12.6	10.7	16.5	17.4	17.2	19.9	27.1
62 years	14.6	11.2	11.8	13.3	11.4	17.4	18.5	18.6	21.5	29.4
63 years	15.2	11.7	12.3	14.0	12.2	18.3	19.6	20.0	23.1	31.7
64 years	15.7	12.2	12.9	14.7	13.1	19.3	20.8	21.5	24.8	34.0
65 years	16.3	12.8	13.5	15.4	13.9	20.2	22.0	23.1	26.5	36.4
66 years	16.9	13.4	14.1	16.2	14.8	21.2	23.2	24.6	28.3	38.8
67 years	17.4	13.9	14.7	16.9	15.8	22.2	24.5	26.3	30.1	41.3
68 years	18.0	14.6	15.4	17.7	16.8	23.1	25.7	27.9	31.9	43.7
69 years	18.6	15.2	16.1	18.5	17.8	24.1	27.0	29.6	33.8	46.1
70 years	19.2	15.8	16.7	19.3	18.9	25.1	28.2	31.2	35.6	48.5
71 years	19.7	16.5	17.4	20.1	19.9	26.1	29.5	32.9	37.5	50.9
72 years	20.3	17.1	18.1	21.0	21.0	27.1	30.7	34.5	39.3	53.2
73 years	20.9	17.8	18.8	21.8	22.1	28.0	32.0	36.1	41.2	55.4
74 years	21.5	18.4	19.5	22.6	23.2	29.0	33.2	37.7	43.0	57.5
75 years	22.0	19.1	20.2	23.4	24.3	29.9	34.3	39.2	44.7	59.6
76 years	22.6	19.8	20.9	24.2	25.4	30.8	35.5	40.7	46.5	61.5
77 years	23.1	20.4	21.6	25.0	26.5	31.7	36.6	42.1	48.1	63.3
78 years	23.6	21.1	22.3	25.8	27.5	32.6	37.6	43.4	49.7	65.1
79 years	24.1	21.7	23.0	26.6	28.6	33.4	38.6	44.6	51.3	66.7

Female subjects
50th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	5.6	5.1	4.9	4.7	4.2	4.2	3.7	3.0	2.1	1.1
21 years	5.7	5.1	5.0	4.7	4.2	4.3	3.7	3.0	2.1	1.1
22 years	5.7	5.1	5.0	4.7	4.2	4.3	3.8	3.1	2.2	1.2
23 years	5.8	5.2	5.0	4.8	4.2	4.4	3.8	3.1	2.2	1.2
24 years	5.9	5.2	5.0	4.8	4.2	4.4	3.9	3.1	2.3	1.3
25 years	6.0	5.2	5.1	4.8	4.3	4.5	3.9	3.2	2.4	1.4
26 years	6.0	5.3	5.1	4.9	4.3	4.6	4.0	3.2	2.4	1.5
27 years	6.1	5.3	5.2	4.9	4.3	4.6	4.1	3.3	2.5	1.6
28 years	6.2	5.3	5.2	5.0	4.3	4.7	4.2	3.3	2.6	1.7
29 years	6.3	5.4	5.3	5.0	4.3	4.8	4.3	3.4	2.7	1.8
30 years	6.4	5.5	5.3	5.1	4.4	4.9	4.4	3.5	2.8	2.0
31 years	6.5	5.5	5.4	5.2	4.4	5.0	4.5	3.6	2.9	2.1
32 years	6.7	5.6	5.5	5.2	4.4	5.1	4.6	3.7	3.1	2.3
33 years	6.8	5.6	5.5	5.3	4.5	5.2	4.7	3.8	3.2	2.5
34 years	6.9	5.7	5.6	5.4	4.5	5.4	4.9	3.9	3.4	2.8
35 years	7.1	5.8	5.7	5.5	4.6	5.5	5.0	4.0	3.6	3.0
36 years	7.2	5.9	5.8	5.6	4.6	5.7	5.2	4.2	3.8	3.3
37 years	7.4	6.0	5.9	5.7	4.7	5.9	5.4	4.4	4.0	3.6
38 years	7.6	6.1	6.0	5.9	4.8	6.1	5.6	4.5	4.3	4.0
39 years	7.8	6.2	6.1	6.0	4.9	6.3	5.9	4.8	4.6	4.4
40 years	8.0	6.3	6.3	6.2	5.0	6.5	6.1	5.0	4.9	4.8
41 years	8.2	6.5	6.4	6.3	5.1	6.8	6.4	5.3	5.2	5.3
42 years	8.4	6.6	6.6	6.5	5.2	7.1	6.7	5.6	5.6	5.9
43 years	8.6	6.8	6.7	6.7	5.3	7.4	7.1	5.9	6.0	6.5
44 years	8.9	6.9	6.9	7.0	5.5	7.7	7.4	6.2	6.5	7.1
45 years	9.2	7.1	7.1	7.2	5.7	8.1	7.8	6.6	7.0	7.9
46 years	9.5	7.3	7.3	7.5	5.8	8.5	8.3	7.1	7.6	8.7
47 years	9.8	7.5	7.5	7.7	6.1	8.9	8.8	7.6	8.2	9.6
48 years	10.1	7.8	7.8	8.0	6.3	9.4	9.3	8.1	8.8	10.6
49 years	10.4	8.0	8.1	8.4	6.6	9.9	9.9	8.7	9.5	11.7
50 years	10.8	8.3	8.4	8.7	6.9	10.4	10.5	9.4	10.3	12.9
51 years	11.1	8.6	8.7	9.1	7.2	11.0	11.1	10.1	11.2	14.2
52 years	11.5	8.9	9.0	9.5	7.6	11.6	11.8	10.9	12.1	15.6
53 years	11.9	9.2	9.4	10.0	8.0	12.3	12.6	11.7	13.1	17.1
54 years	12.3	9.5	9.7	10.5	8.5	13.0	13.4	12.7	14.2	18.7
55 years	12.8	9.9	10.1	11.0	9.0	13.8	14.3	13.7	15.3	20.4
56 years	13.3	10.3	10.6	11.5	9.6	14.6	15.2	14.8	16.6	22.2
57 years	13.7	10.7	11.0	12.1	10.2	15.4	16.2	15.9	17.9	24.2
58 years	14.2	11.2	11.5	12.7	10.9	16.3	17.2	17.2	19.3	26.2
59 years	14.7	11.6	12.1	13.4	11.6	17.2	18.3	18.5	20.8	28.4
60 years	15.3	12.1	12.6	14.1	12.4	18.2	19.4	19.9	22.3	30.6
61 years	15.8	12.7	13.2	14.8	13.3	19.2	20.6	21.3	23.9	32.9
62 years	16.4	13.2	13.8	15.6	14.2	20.2	21.8	22.9	25.6	35.3
63 years	16.9	13.8	14.4	16.4	15.2	21.3	23.0	24.4	27.4	37.7
64 years	17.5	14.4	15.1	17.2	16.2	22.4	24.3	26.1	29.2	40.2
65 years	18.1	15.0	15.8	18.1	17.3	23.5	25.6	27.7	31.0	42.7
66 years	18.7	15.7	16.5	18.9	18.5	24.6	27.0	29.5	32.9	45.1
67 years	19.4	16.3	17.2	19.9	19.7	25.8	28.3	31.2	34.8	47.6
68 years	20.0	17.0	18.0	20.8	21.0	26.9	29.7	32.9	36.7	50.0
69 years	20.6	17.7	18.8	21.7	22.3	28.1	31.0	34.6	38.7	52.4
70 years	21.3	18.5	19.6	22.7	23.6	29.3	32.4	36.3	40.6	54.7
71 years	21.9	19.2	20.4	23.7	25.0	30.4	33.7	38.0	42.5	56.9
72 years	22.5	20.0	21.2	24.6	26.3	31.5	35.0	39.7	44.4	59.0
73 years	23.2	20.7	22.0	25.6	27.7	32.6	36.3	41.3	46.2	61.0
74 years	23.8	21.5	22.9	26.6	29.0	33.7	37.6	42.8	48.0	63.0
75 years	24.5	22.3	23.7	27.5	30.3	34.7	38.8	44.3	49.7	64.8
76 years	25.1	23.1	24.6	28.5	31.6	35.8	39.9	45.7	51.4	66.5
77 years	25.7	23.8	25.4	29.4	32.8	36.7	41.1	47.0	53.0	68.1
78 years	26.3	24.6	26.2	30.3	34.0	37.7	42.1	48.3	54.5	69.6
79 years	26.9	25.4	27.0	31.2	35.1	38.6	43.2	49.5	55.9	71.0

Female subjects
60th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	7.1	6.5	6.4	6.2	5.8	5.9	5.5	4.9	4.1	3.2
21 years	7.2	6.6	6.4	6.3	5.8	5.9	5.5	4.9	4.1	3.3
22 years	7.2	6.6	6.4	6.3	5.8	6.0	5.6	4.9	4.2	3.4
23 years	7.3	6.6	6.5	6.3	5.9	6.0	5.6	5.0	4.2	3.4
24 years	7.4	6.6	6.5	6.3	5.9	6.1	5.7	5.0	4.3	3.5
25 years	7.5	6.7	6.5	6.4	5.9	6.1	5.8	5.1	4.4	3.6
26 years	7.5	6.7	6.5	6.4	5.9	6.2	5.8	5.1	4.4	3.7
27 years	7.6	6.7	6.6	6.5	5.9	6.3	5.9	5.2	4.5	3.8
28 years	7.7	6.8	6.6	6.5	5.9	6.3	6.0	5.2	4.6	4.0
29 years	7.8	6.8	6.7	6.6	6.0	6.4	6.1	5.3	4.7	4.1
30 years	7.9	6.9	6.7	6.6	6.0	6.5	6.2	5.4	4.9	4.3
31 years	8.0	6.9	6.8	6.7	6.0	6.6	6.3	5.5	5.0	4.5
32 years	8.2	7.0	6.8	6.8	6.1	6.7	6.5	5.6	5.1	4.7
33 years	8.3	7.1	6.9	6.9	6.1	6.9	6.6	5.7	5.3	4.9
34 years	8.4	7.1	7.0	7.0	6.1	7.0	6.8	5.9	5.5	5.2
35 years	8.6	7.2	7.0	7.1	6.2	7.2	7.0	6.0	5.7	5.5
36 years	8.7	7.3	7.1	7.2	6.3	7.3	7.2	6.2	5.9	5.8
37 years	8.9	7.4	7.2	7.3	6.3	7.5	7.4	6.4	6.2	6.2
38 years	9.1	7.5	7.3	7.4	6.4	7.7	7.7	6.6	6.5	6.6
39 years	9.3	7.6	7.4	7.6	6.5	8.0	7.9	6.9	6.8	7.1
40 years	9.5	7.7	7.6	7.7	6.6	8.2	8.2	7.2	7.1	7.6
41 years	9.7	7.9	7.7	7.9	6.7	8.5	8.5	7.5	7.5	8.1
42 years	10.0	8.0	7.9	8.1	6.9	8.8	8.9	7.8	7.9	8.8
43 years	10.2	8.2	8.0	8.3	7.0	9.1	9.3	8.2	8.4	9.5
44 years	10.5	8.4	8.2	8.5	7.2	9.5	9.7	8.6	8.9	10.3
45 years	10.8	8.6	8.4	8.8	7.4	9.8	10.2	9.1	9.5	11.1
46 years	11.1	8.8	8.6	9.1	7.6	10.3	10.7	9.6	10.1	12.0
47 years	11.4	9.0	8.9	9.4	7.8	10.7	11.2	10.2	10.8	13.1
48 years	11.7	9.3	9.2	9.7	8.1	11.2	11.8	10.8	11.5	14.2
49 years	12.1	9.5	9.5	10.0	8.4	11.7	12.5	11.5	12.3	15.4
50 years	12.5	9.8	9.8	10.4	8.8	12.3	13.2	12.2	13.2	16.8
51 years	12.9	10.1	10.1	10.8	9.1	13.0	13.9	13.1	14.2	18.2
52 years	13.3	10.5	10.5	11.3	9.6	13.6	14.7	14.0	15.2	19.8
53 years	13.7	10.9	10.9	11.8	10.1	14.3	15.6	14.9	16.3	21.5
54 years	14.2	11.3	11.3	12.3	10.6	15.1	16.5	16.0	17.5	23.2
55 years	14.7	11.7	11.8	12.8	11.2	15.9	17.4	17.1	18.8	25.1
56 years	15.2	12.1	12.3	13.4	11.9	16.8	18.5	18.3	20.2	27.1
57 years	15.7	12.6	12.9	14.1	12.6	17.7	19.6	19.7	21.7	29.2
58 years	16.2	13.2	13.5	14.8	13.4	18.7	20.7	21.0	23.2	31.4
59 years	16.8	13.7	14.1	15.5	14.3	19.7	21.9	22.5	24.8	33.7
60 years	17.4	14.3	14.8	16.3	15.2	20.7	23.1	24.0	26.5	36.0
61 years	18.0	14.9	15.5	17.1	16.3	21.8	24.4	25.6	28.3	38.4
62 years	18.6	15.6	16.2	17.9	17.4	23.0	25.7	27.3	30.1	40.9
63 years	19.3	16.3	17.0	18.8	18.5	24.1	27.1	29.0	32.0	43.3
64 years	19.9	17.0	17.9	19.7	19.8	25.3	28.5	30.7	33.9	45.8
65 years	20.6	17.8	18.7	20.7	21.1	26.6	29.9	32.5	35.9	48.2
66 years	21.3	18.6	19.6	21.7	22.5	27.8	31.3	34.3	37.8	50.6
67 years	22.0	19.4	20.6	22.7	23.9	29.1	32.7	36.1	39.8	53.0
68 years	22.7	20.3	21.5	23.8	25.4	30.3	34.2	37.9	41.8	55.3
69 years	23.4	21.2	22.5	24.8	26.9	31.6	35.6	39.6	43.8	57.5
70 years	24.2	22.1	23.5	25.9	28.4	32.9	37.0	41.3	45.7	59.6
71 years	24.9	23.0	24.6	27.0	29.9	34.1	38.4	43.0	47.6	61.7
72 years	25.6	24.0	25.6	28.1	31.5	35.3	39.7	44.6	49.4	63.6
73 years	26.4	24.9	26.7	29.2	33.0	36.5	41.0	46.2	51.2	65.4
74 years	27.1	25.9	27.7	30.3	34.4	37.7	42.3	47.7	53.0	67.1
75 years	27.8	26.8	28.8	31.4	35.8	38.8	43.5	49.1	54.6	68.7
76 years	28.6	27.8	29.8	32.5	37.2	39.9	44.7	50.5	56.2	70.2
77 years	29.3	28.7	30.8	33.5	38.5	41.0	45.8	51.7	57.7	71.6
78 years	30.0	29.6	31.8	34.5	39.8	42.0	46.9	52.9	59.1	72.8
79 years	30.7	30.6	32.8	35.5	40.9	42.9	47.9	54.0	60.4	74.0

Female subjects
70th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	8.5	8.1	8.0	7.8	7.5	7.5	7.4	6.8	6.1	5.4
21 years	8.6	8.1	8.0	7.8	7.5	7.5	7.4	6.9	6.1	5.5
22 years	8.7	8.1	8.0	7.8	7.5	7.5	7.5	6.9	6.2	5.6
23 years	8.7	8.2	8.0	7.9	7.5	7.6	7.6	7.0	6.2	5.6
24 years	8.8	8.2	8.1	7.9	7.5	7.6	7.6	7.0	6.3	5.7
25 years	8.9	8.2	8.1	7.9	7.5	7.7	7.7	7.1	6.4	5.8
26 years	8.9	8.3	8.1	8.0	7.5	7.7	7.8	7.2	6.4	5.9
27 years	9.0	8.3	8.2	8.0	7.6	7.8	7.9	7.3	6.5	6.1
28 years	9.1	8.4	8.2	8.1	7.6	7.9	8.0	7.4	6.6	6.2
29 years	9.2	8.4	8.3	8.1	7.6	8.0	8.2	7.5	6.8	6.4
30 years	9.3	8.5	8.3	8.2	7.6	8.0	8.3	7.6	6.9	6.6
31 years	9.4	8.5	8.4	8.2	7.7	8.1	8.5	7.7	7.0	6.8
32 years	9.6	8.6	8.4	8.3	7.7	8.3	8.6	7.9	7.2	7.0
33 years	9.7	8.7	8.5	8.4	7.8	8.4	8.8	8.0	7.4	7.3
34 years	9.9	8.7	8.6	8.5	7.8	8.5	9.0	8.2	7.6	7.6
35 years	10.0	8.8	8.7	8.6	7.9	8.7	9.3	8.4	7.8	8.0
36 years	10.2	8.9	8.8	8.7	7.9	8.8	9.5	8.7	8.1	8.4
37 years	10.4	9.0	8.9	8.8	8.0	9.0	9.8	8.9	8.3	8.8
38 years	10.6	9.1	9.0	9.0	8.1	9.2	10.1	9.2	8.7	9.3
39 years	10.8	9.3	9.1	9.1	8.2	9.4	10.4	9.5	9.0	9.8
40 years	11.0	9.4	9.3	9.3	8.3	9.7	10.8	9.9	9.4	10.4
41 years	11.3	9.6	9.4	9.5	8.5	10.0	11.2	10.2	9.8	11.1
42 years	11.5	9.7	9.6	9.7	8.6	10.3	11.6	10.7	10.3	11.8
43 years	11.8	9.9	9.8	9.9	8.8	10.6	12.1	11.1	10.9	12.6
44 years	12.1	10.1	10.0	10.1	9.0	11.0	12.6	11.7	11.5	13.6
45 years	12.4	10.4	10.2	10.4	9.2	11.4	13.1	12.2	12.1	14.6
46 years	12.8	10.6	10.5	10.7	9.4	11.9	13.7	12.9	12.8	15.7
47 years	13.1	10.9	10.8	11.0	9.7	12.4	14.4	13.5	13.6	16.9
48 years	13.5	11.2	11.1	11.4	10.1	12.9	15.1	14.3	14.5	18.2
49 years	13.9	11.5	11.4	11.8	10.4	13.5	15.8	15.1	15.4	19.6
50 years	14.4	11.8	11.8	12.2	10.8	14.2	16.6	16.0	16.4	21.2
51 years	14.9	12.2	12.2	12.6	11.3	14.9	17.5	16.9	17.5	22.8
52 years	15.3	12.6	12.6	13.1	11.8	15.6	18.4	18.0	18.7	24.6
53 years	15.9	13.0	13.1	13.7	12.4	16.5	19.4	19.1	20.0	26.5
54 years	16.4	13.5	13.6	14.3	13.0	17.3	20.4	20.2	21.4	28.5
55 years	17.0	14.0	14.2	14.9	13.7	18.3	21.5	21.5	22.9	30.7
56 years	17.6	14.5	14.8	15.6	14.5	19.3	22.6	22.8	24.5	32.9
57 years	18.2	15.1	15.4	16.3	15.4	20.4	23.8	24.2	26.1	35.2
58 years	18.9	15.7	16.1	17.1	16.3	21.5	25.0	25.7	27.9	37.5
59 years	19.6	16.4	16.9	17.9	17.4	22.7	26.3	27.3	29.7	40.0
60 years	20.3	17.1	17.6	18.8	18.5	23.9	27.7	28.8	31.6	42.4
61 years	21.0	17.8	18.5	19.8	19.7	25.2	29.0	30.5	33.5	44.9
62 years	21.8	18.6	19.4	20.8	21.0	26.6	30.4	32.2	35.5	47.4
63 years	22.6	19.4	20.3	21.8	22.4	28.0	31.9	33.9	37.6	49.9
64 years	23.4	20.3	21.3	22.9	23.8	29.4	33.3	35.6	39.6	52.3
65 years	24.2	21.2	22.3	24.0	25.4	30.8	34.8	37.4	41.7	54.7
66 years	25.1	22.1	23.3	25.2	26.9	32.3	36.2	39.1	43.8	57.0
67 years	26.0	23.1	24.4	26.4	28.6	33.7	37.7	40.9	45.8	59.2
68 years	26.8	24.1	25.5	27.6	30.2	35.2	39.1	42.6	47.8	61.3
69 years	27.7	25.1	26.7	28.8	31.9	36.6	40.5	44.3	49.8	63.3
70 years	28.6	26.2	27.8	30.1	33.6	38.1	41.9	45.9	51.7	65.3
71 years	29.5	27.3	29.0	31.3	35.3	39.5	43.3	47.5	53.6	67.0
72 years	30.4	28.3	30.2	32.6	36.9	40.8	44.6	49.0	55.3	68.7
73 years	31.3	29.4	31.4	33.9	38.5	42.1	45.9	50.5	57.0	70.3
74 years	32.2	30.5	32.6	35.1	40.1	43.4	47.1	51.9	58.6	71.7
75 years	33.0	31.6	33.7	36.3	41.6	44.6	48.3	53.2	60.2	73.0
76 years	33.9	32.7	34.9	37.5	43.0	45.8	49.4	54.4	61.6	74.3
77 years	34.8	33.7	36.0	38.7	44.3	46.9	50.5	55.6	62.9	75.4
78 years	35.6	34.8	37.1	39.8	45.6	47.9	51.5	56.7	64.1	76.4
79 years	36.4	35.8	38.2	40.9	46.7	48.9	52.4	57.7	65.3	77.3

Female subjects
80th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	10.3	9.7	9.7	9.4	9.1	9.1	9.3	8.8	8.1	7.7
21 years	10.4	9.8	9.7	9.4	9.1	9.2	9.4	8.9	8.2	7.8
22 years	10.4	9.8	9.7	9.5	9.1	9.2	9.5	9.0	8.2	7.9
23 years	10.5	9.9	9.8	9.5	9.2	9.2	9.6	9.0	8.3	8.0
24 years	10.6	9.9	9.8	9.5	9.2	9.3	9.7	9.1	8.4	8.1
25 years	10.7	10.0	9.9	9.6	9.2	9.3	9.8	9.2	8.5	8.3
26 years	10.8	10.0	9.9	9.6	9.2	9.4	9.9	9.3	8.6	8.4
27 years	10.9	10.1	10.0	9.7	9.3	9.5	10.1	9.5	8.7	8.6
28 years	11.0	10.1	10.1	9.7	9.3	9.5	10.2	9.6	8.8	8.8
29 years	11.2	10.2	10.1	9.8	9.3	9.6	10.4	9.7	9.0	9.0
30 years	11.3	10.3	10.2	9.9	9.4	9.7	10.6	9.9	9.1	9.3
31 years	11.4	10.4	10.3	10.0	9.4	9.8	10.8	10.1	9.3	9.6
32 years	11.6	10.5	10.4	10.1	9.5	10.0	11.0	10.3	9.5	9.9
33 years	11.8	10.6	10.5	10.2	9.6	10.1	11.2	10.5	9.8	10.3
34 years	12.0	10.7	10.7	10.3	9.6	10.2	11.5	10.8	10.0	10.7
35 years	12.2	10.8	10.8	10.4	9.7	10.4	11.8	11.0	10.3	11.1
36 years	12.4	10.9	10.9	10.5	9.8	10.6	12.1	11.4	10.6	11.6
37 years	12.6	11.1	11.1	10.7	9.9	10.8	12.4	11.7	11.0	12.2
38 years	12.9	11.2	11.3	10.8	10.1	11.0	12.8	12.1	11.4	12.8
39 years	13.1	11.4	11.5	11.0	10.2	11.3	13.2	12.5	11.8	13.5
40 years	13.4	11.6	11.7	11.2	10.4	11.6	13.7	12.9	12.3	14.3
41 years	13.7	11.8	11.9	11.4	10.5	11.9	14.1	13.4	12.9	15.2
42 years	14.0	12.1	12.1	11.7	10.8	12.3	14.7	14.0	13.5	16.1
43 years	14.4	12.3	12.4	12.0	11.0	12.7	15.2	14.5	14.1	17.1
44 years	14.8	12.6	12.7	12.3	11.3	13.1	15.8	15.2	14.9	18.3
45 years	15.1	12.9	13.0	12.6	11.6	13.6	16.5	15.9	15.7	19.6
46 years	15.6	13.2	13.4	13.0	11.9	14.2	17.2	16.7	16.5	20.9
47 years	16.0	13.5	13.7	13.4	12.3	14.8	18.0	17.5	17.5	22.4
48 years	16.5	13.9	14.2	13.8	12.7	15.5	18.8	18.4	18.6	24.0
49 years	17.0	14.3	14.6	14.3	13.2	16.2	19.6	19.3	19.7	25.7
50 years	17.5	14.7	15.1	14.8	13.7	17.0	20.6	20.4	20.9	27.5
51 years	18.1	15.2	15.6	15.4	14.3	17.8	21.5	21.5	22.3	29.5
52 years	18.6	15.7	16.2	16.0	15.0	18.8	22.6	22.6	23.7	31.5
53 years	19.2	16.3	16.7	16.7	15.7	19.8	23.7	23.9	25.2	33.7
54 years	19.9	16.8	17.4	17.4	16.6	20.9	24.8	25.2	26.8	35.9
55 years	20.6	17.4	18.1	18.2	17.5	22.0	26.0	26.6	28.5	38.2
56 years	21.3	18.1	18.8	19.0	18.4	23.3	27.3	28.0	30.3	40.6
57 years	22.0	18.8	19.6	19.9	19.5	24.6	28.5	29.6	32.2	43.0
58 years	22.8	19.5	20.4	20.8	20.7	25.9	29.9	31.1	34.1	45.5
59 years	23.5	20.3	21.2	21.8	21.9	27.4	31.2	32.7	36.1	47.9
60 years	24.4	21.1	22.1	22.9	23.3	28.9	32.6	34.4	38.2	50.3
61 years	25.2	22.0	23.1	24.0	24.7	30.4	34.1	36.1	40.2	52.7
62 years	26.1	22.9	24.1	25.2	26.2	32.0	35.5	37.8	42.3	55.1
63 years	26.9	23.9	25.1	26.4	27.8	33.6	37.0	39.5	44.4	57.4
64 years	27.8	24.8	26.2	27.7	29.4	35.3	38.4	41.2	46.5	59.6
65 years	28.8	25.8	27.3	29.0	31.1	36.9	39.9	42.9	48.6	61.7
66 years	29.7	26.9	28.4	30.3	32.8	38.6	41.4	44.6	50.6	63.7
67 years	30.6	28.0	29.6	31.7	34.6	40.2	42.8	46.2	52.6	65.6
68 years	31.6	29.1	30.7	33.0	36.3	41.8	44.2	47.9	54.5	67.4
69 years	32.6	30.2	31.9	34.4	38.1	43.3	45.6	49.4	56.3	69.1
70 years	33.5	31.3	33.1	35.8	39.8	44.9	46.9	51.0	58.1	70.6
71 years	34.5	32.4	34.3	37.2	41.5	46.3	48.3	52.4	59.8	72.1
72 years	35.4	33.6	35.5	38.6	43.1	47.7	49.5	53.8	61.3	73.4
73 years	36.4	34.7	36.7	39.9	44.7	49.1	50.7	55.2	62.8	74.6
74 years	37.3	35.9	37.9	41.2	46.2	50.3	51.9	56.4	64.2	75.7
75 years	38.3	37.0	39.1	42.5	47.7	51.5	53.0	57.6	65.5	76.7
76 years	39.2	38.1	40.2	43.8	49.0	52.6	54.1	58.7	66.7	77.7
77 years	40.1	39.2	41.3	44.9	50.3	53.7	55.1	59.8	67.8	78.5
78 years	40.9	40.3	42.4	46.1	51.5	54.6	56.0	60.8	68.8	79.2
79 years	41.8	41.3	43.4	47.2	52.5	55.5	56.9	61.7	69.7	79.9

Female subjects
90th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	12.1	11.7	11.7	11.1	11.1	11.5	11.4	11.0	10.3	10.0
21 years	12.2	11.7	11.7	11.1	11.1	11.6	11.6	11.1	10.4	10.1
22 years	12.3	11.8	11.8	11.2	11.2	11.7	11.7	11.2	10.5	10.3
23 years	12.4	11.9	11.9	11.2	11.3	11.8	11.8	11.3	10.6	10.4
24 years	12.5	12.0	12.0	11.3	11.3	12.0	12.0	11.5	10.7	10.6
25 years	12.6	12.1	12.1	11.3	11.4	12.1	12.1	11.6	10.9	10.8
26 years	12.8	12.2	12.2	11.4	11.5	12.3	12.3	11.8	11.0	11.0
27 years	12.9	12.3	12.3	11.5	11.6	12.4	12.5	12.0	11.2	11.2
28 years	13.1	12.4	12.5	11.5	11.7	12.6	12.7	12.2	11.4	11.5
29 years	13.3	12.5	12.6	11.6	11.8	12.9	13.0	12.4	11.6	11.8
30 years	13.5	12.7	12.8	11.8	12.0	13.1	13.2	12.7	11.9	12.2
31 years	13.7	12.8	13.0	11.9	12.1	13.3	13.5	12.9	12.1	12.6
32 years	13.9	13.0	13.1	12.0	12.3	13.6	13.8	13.2	12.4	13.0
33 years	14.1	13.2	13.4	12.2	12.5	13.9	14.2	13.6	12.8	13.5
34 years	14.4	13.4	13.6	12.3	12.7	14.3	14.6	14.0	13.2	14.1
35 years	14.7	13.6	13.8	12.5	12.9	14.7	15.0	14.4	13.6	14.7
36 years	15.0	13.9	14.1	12.7	13.1	15.1	15.4	14.8	14.1	15.5
37 years	15.3	14.1	14.4	13.0	13.4	15.5	15.9	15.3	14.6	16.3
38 years	15.6	14.4	14.7	13.2	13.7	16.0	16.4	15.9	15.2	17.1
39 years	16.0	14.7	15.0	13.5	14.1	16.5	17.0	16.5	15.8	18.1
40 years	16.4	15.0	15.4	13.9	14.4	17.1	17.6	17.1	16.5	19.2
41 years	16.8	15.4	15.8	14.2	14.8	17.7	18.3	17.8	17.3	20.4
42 years	17.3	15.8	16.2	14.6	15.3	18.4	19.0	18.6	18.2	21.7
43 years	17.7	16.2	16.6	15.1	15.8	19.1	19.7	19.4	19.1	23.2
44 years	18.3	16.6	17.1	15.6	16.3	19.8	20.6	20.3	20.2	24.7
45 years	18.8	17.1	17.7	16.1	16.9	20.7	21.4	21.3	21.3	26.4
46 years	19.4	17.6	18.2	16.7	17.6	21.5	22.4	22.3	22.5	28.2
47 years	20.0	18.1	18.8	17.4	18.3	22.5	23.3	23.4	23.8	30.2
48 years	20.6	18.7	19.4	18.1	19.0	23.5	24.4	24.6	25.3	32.3
49 years	21.3	19.3	20.1	18.9	19.8	24.5	25.5	25.8	26.8	34.4
50 years	22.0	19.9	20.8	19.8	20.7	25.6	26.7	27.1	28.4	36.7
51 years	22.7	20.6	21.6	20.7	21.7	26.8	27.9	28.5	30.1	39.0
52 years	23.5	21.3	22.4	21.7	22.7	28.0	29.1	30.0	31.9	41.5
53 years	24.3	22.1	23.3	22.7	23.8	29.3	30.5	31.5	33.7	43.9
54 years	25.2	22.9	24.1	23.9	24.9	30.6	31.8	33.1	35.7	46.5
55 years	26.1	23.7	25.1	25.1	26.1	31.9	33.2	34.7	37.7	49.0
56 years	27.0	24.6	26.0	26.4	27.4	33.3	34.6	36.3	39.7	51.5
57 years	27.9	25.5	27.1	27.7	28.7	34.8	36.1	38.0	41.8	53.9
58 years	28.9	26.5	28.1	29.2	30.1	36.2	37.6	39.8	44.0	56.4
59 years	29.9	27.5	29.2	30.6	31.6	37.7	39.1	41.5	46.1	58.7
60 years	30.9	28.5	30.3	32.2	33.0	39.1	40.6	43.2	48.2	60.9
61 years	31.9	29.6	31.4	33.7	34.6	40.6	42.1	44.9	50.3	63.1
62 years	33.0	30.7	32.6	35.3	36.1	42.1	43.6	46.7	52.3	65.1
63 years	34.1	31.8	33.8	36.9	37.6	43.5	45.1	48.3	54.3	67.1
64 years	35.2	32.9	35.0	38.5	39.2	45.0	46.6	50.0	56.2	68.9
65 years	36.2	34.1	36.2	40.2	40.8	46.4	48.0	51.6	58.1	70.5
66 years	37.3	35.2	37.4	41.8	42.3	47.7	49.4	53.2	59.9	72.1
67 years	38.4	36.4	38.6	43.3	43.8	49.1	50.8	54.7	61.6	73.5
68 years	39.5	37.6	39.8	44.9	45.3	50.4	52.1	56.1	63.2	74.8
69 years	40.6	38.7	41.0	46.4	46.8	51.6	53.4	57.5	64.7	76.0
70 years	41.6	39.9	42.2	47.8	48.2	52.8	54.7	58.8	66.0	77.0
71 years	42.7	41.0	43.4	49.2	49.6	53.9	55.8	60.0	67.3	78.0
72 years	43.7	42.2	44.5	50.5	50.9	55.0	56.9	61.2	68.6	78.9
73 years	44.7	43.3	45.6	51.8	52.1	56.0	58.0	62.2	69.7	79.7
74 years	45.7	44.4	46.7	53.0	53.3	57.0	59.0	63.3	70.7	80.4
75 years	46.6	45.4	47.8	54.1	54.4	57.9	60.0	64.2	71.6	81.0
76 years	47.6	46.5	48.8	55.1	55.5	58.7	60.8	65.1	72.5	81.5
77 years	48.4	47.5	49.8	56.1	56.4	59.5	61.7	65.9	73.2	82.0
78 years	49.3	48.5	50.7	57.0	57.4	60.3	62.5	66.7	73.9	82.5
79 years	50.1	49.4	51.6	57.8	58.2	60.9	63.2	67.3	74.6	82.9

Male subjects
10th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	-1.9	-2.6	-1.9	-1.2	-3.8	-1.7	-2.8	-2.9	-3.1	-2.9
21 years	-1.8	-2.5	-1.8	-1.1	-3.8	-1.6	-2.7	-2.8	-3.0	-2.8
22 years	-1.7	-2.4	-1.7	-1.0	-3.8	-1.5	-2.6	-2.7	-3.0	-2.8
23 years	-1.6	-2.3	-1.6	-1.0	-3.7	-1.3	-2.6	-2.7	-3.0	-2.8
24 years	-1.5	-2.2	-1.5	-0.8	-3.7	-1.2	-2.5	-2.6	-2.9	-2.7
25 years	-1.4	-2.1	-1.4	-0.7	-3.7	-1.1	-2.3	-2.5	-2.9	-2.7
26 years	-1.3	-2.0	-1.3	-0.6	-3.6	-1.0	-2.2	-2.3	-2.8	-2.6
27 years	-1.1	-1.9	-1.2	-0.5	-3.6	-0.9	-2.1	-2.2	-2.7	-2.6
28 years	-1.0	-1.8	-1.1	-0.4	-3.5	-0.7	-2.0	-2.1	-2.7	-2.5
29 years	-0.9	-1.7	-1.0	-0.3	-3.5	-0.6	-1.9	-2.0	-2.6	-2.5
30 years	-0.7	-1.6	-0.9	-0.2	-3.4	-0.5	-1.7	-1.8	-2.5	-2.4
31 years	-0.6	-1.5	-0.7	-0.1	-3.4	-0.3	-1.6	-1.6	-2.4	-2.3
32 years	-0.4	-1.4	-0.6	0.1	-3.3	-0.2	-1.4	-1.5	-2.3	-2.2
33 years	-0.3	-1.2	-0.5	0.2	-3.2	0.0	-1.2	-1.3	-2.2	-2.1
34 years	-0.1	-1.1	-0.3	0.3	-3.2	0.1	-1.0	-1.1	-2.1	-1.9
35 years	0.1	-1.0	-0.2	0.5	-3.1	0.3	-0.8	-0.9	-2.0	-1.8
36 years	0.3	-0.8	-0.1	0.6	-3.0	0.5	-0.6	-0.6	-1.8	-1.6
37 years	0.4	-0.7	0.1	0.8	-2.9	0.6	-0.4	-0.4	-1.7	-1.5
38 years	0.6	-0.5	0.2	0.9	-2.8	0.8	-0.1	-0.1	-1.5	-1.3
39 years	0.8	-0.4	0.4	1.1	-2.7	1.0	0.1	0.2	-1.3	-1.0
40 years	1.0	-0.2	0.5	1.2	-2.6	1.2	0.4	0.5	-1.1	-0.8
41 years	1.2	0.0	0.7	1.4	-2.5	1.4	0.7	0.9	-0.9	-0.5
42 years	1.5	0.1	0.9	1.5	-2.4	1.6	1.0	1.2	-0.6	-0.2
43 years	1.7	0.3	1.1	1.7	-2.3	1.8	1.3	1.6	-0.3	0.2
44 years	1.9	0.5	1.2	1.9	-2.2	2.1	1.6	2.0	0.0	0.6
45 years	2.1	0.7	1.4	2.1	-2.0	2.3	2.0	2.5	0.3	1.0
46 years	2.4	0.9	1.6	2.2	-1.9	2.5	2.4	3.0	0.6	1.5
47 years	2.6	1.1	1.8	2.4	-1.8	2.8	2.8	3.5	1.0	2.1
48 years	2.9	1.4	2.0	2.6	-1.6	3.0	3.2	4.0	1.4	2.7
49 years	3.2	1.6	2.2	2.8	-1.4	3.3	3.7	4.6	1.9	3.4
50 years	3.5	1.8	2.4	3.0	-1.2	3.6	4.1	5.2	2.3	4.1
51 years	3.7	2.1	2.7	3.2	-1.1	3.9	4.6	5.8	2.9	4.9
52 years	4.0	2.3	2.9	3.4	-0.8	4.1	5.1	6.5	3.4	5.8
53 years	4.3	2.6	3.1	3.6	-0.6	4.4	5.7	7.2	4.1	6.8
54 years	4.6	2.9	3.3	3.9	-0.4	4.7	6.3	8.0	4.7	7.9
55 years	5.0	3.1	3.6	4.1	-0.2	5.1	6.9	8.8	5.4	9.0
56 years	5.3	3.4	3.8	4.3	0.1	5.4	7.5	9.6	6.2	10.3
57 years	5.6	3.7	4.1	4.5	0.3	5.7	8.1	10.5	7.0	11.6
58 years	6.0	4.0	4.4	4.8	0.6	6.0	8.8	11.4	7.8	13.0
59 years	6.3	4.3	4.6	5.0	0.9	6.4	9.5	12.4	8.8	14.6
60 years	6.7	4.7	4.9	5.3	1.2	6.8	10.2	13.3	9.7	16.2
61 years	7.1	5.0	5.2	5.5	1.6	7.1	11.0	14.4	10.8	17.9
62 years	7.4	5.3	5.5	5.8	1.9	7.5	11.8	15.4	11.8	19.7
63 years	7.8	5.7	5.8	6.1	2.3	7.9	12.6	16.5	13.0	21.5
64 years	8.2	6.0	6.1	6.3	2.6	8.3	13.4	17.6	14.2	23.4
65 years	8.6	6.4	6.4	6.6	3.0	8.7	14.3	18.7	15.4	25.4
66 years	9.0	6.8	6.7	6.9	3.5	9.1	15.1	19.9	16.7	27.3
67 years	9.5	7.2	7.0	7.2	3.9	9.5	16.0	21.1	18.0	29.3
68 years	9.9	7.6	7.3	7.5	4.4	9.9	16.9	22.3	19.4	31.4
69 years	10.3	8.0	7.7	7.8	4.8	10.4	17.9	23.5	20.8	33.3
70 years	10.8	8.4	8.0	8.1	5.3	10.8	18.8	24.7	22.3	35.3
71 years	11.2	8.8	8.4	8.4	5.8	11.3	19.8	25.9	23.7	37.2
72 years	11.7	9.3	8.7	8.7	6.4	11.7	20.7	27.1	25.2	39.1
73 years	12.2	9.7	9.1	9.0	6.9	12.2	21.7	28.3	26.7	40.9
74 years	12.7	10.2	9.5	9.3	7.5	12.7	22.7	29.5	28.2	42.7
75 years	13.1	10.6	9.8	9.6	8.1	13.2	23.7	30.7	29.7	44.4
76 years	13.6	11.1	10.2	10.0	8.8	13.7	24.7	31.8	31.2	45.9
77 years	14.1	11.6	10.6	10.3	9.4	14.2	25.7	33.0	32.7	47.4
78 years	14.6	12.1	11.0	10.7	10.1	14.7	26.7	34.1	34.1	48.8
79 years	15.1	12.6	11.4	11.0	10.7	15.2	27.6	35.2	35.6	50.1

Male subjects
20th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	0.4	-0.7	0.0	0.9	-1.6	-0.2	-1.2	-1.6	-1.7	-1.5
21 years	0.5	-0.6	0.1	1.0	-1.5	0.0	-1.1	-1.5	-1.7	-1.5
22 years	0.6	-0.5	0.2	1.1	-1.4	0.1	-1.0	-1.4	-1.7	-1.4
23 years	0.8	-0.4	0.3	1.2	-1.4	0.2	-0.9	-1.3	-1.6	-1.4
24 years	0.9	-0.3	0.4	1.3	-1.3	0.4	-0.8	-1.2	-1.5	-1.3
25 years	1.1	-0.2	0.5	1.5	-1.2	0.5	-0.6	-1.1	-1.5	-1.3
26 years	1.2	0.0	0.6	1.6	-1.1	0.6	-0.5	-1.0	-1.4	-1.2
27 years	1.4	0.1	0.8	1.7	-1.0	0.8	-0.3	-0.9	-1.3	-1.1
28 years	1.5	0.2	0.9	1.8	-0.9	1.0	-0.2	-0.7	-1.2	-1.0
29 years	1.7	0.3	1.0	2.0	-0.8	1.1	0.0	-0.5	-1.1	-0.9
30 years	1.8	0.5	1.2	2.1	-0.7	1.3	0.2	-0.4	-1.0	-0.8
31 years	2.0	0.6	1.3	2.3	-0.6	1.5	0.4	-0.2	-0.9	-0.7
32 years	2.2	0.8	1.4	2.4	-0.5	1.7	0.6	0.1	-0.7	-0.5
33 years	2.4	0.9	1.6	2.6	-0.4	1.9	0.8	0.3	-0.6	-0.4
34 years	2.5	1.1	1.7	2.7	-0.2	2.1	1.1	0.5	-0.4	-0.2
35 years	2.7	1.2	1.9	2.9	-0.1	2.3	1.3	0.8	-0.2	0.0
36 years	2.9	1.4	2.0	3.1	0.0	2.5	1.6	1.1	0.0	0.3
37 years	3.1	1.6	2.2	3.2	0.2	2.8	1.9	1.5	0.2	0.5
38 years	3.3	1.8	2.4	3.4	0.4	3.0	2.2	1.8	0.5	0.8
39 years	3.6	2.0	2.5	3.6	0.5	3.2	2.6	2.2	0.8	1.2
40 years	3.8	2.2	2.7	3.8	0.7	3.5	2.9	2.6	1.1	1.6
41 years	4.0	2.4	2.9	4.0	0.9	3.8	3.3	3.1	1.5	2.0
42 years	4.2	2.6	3.1	4.2	1.1	4.0	3.7	3.5	1.8	2.5
43 years	4.5	2.8	3.3	4.4	1.3	4.3	4.1	4.1	2.3	3.0
44 years	4.7	3.0	3.4	4.6	1.5	4.6	4.6	4.6	2.7	3.6
45 years	5.0	3.2	3.6	4.8	1.7	4.9	5.1	5.2	3.3	4.3
46 years	5.3	3.5	3.9	5.0	1.9	5.3	5.6	5.9	3.8	5.1
47 years	5.5	3.7	4.1	5.2	2.2	5.6	6.1	6.6	4.4	5.9
48 years	5.8	4.0	4.3	5.4	2.4	5.9	6.7	7.3	5.1	6.8
49 years	6.1	4.3	4.5	5.6	2.7	6.3	7.2	8.1	5.9	7.8
50 years	6.4	4.5	4.7	5.9	2.9	6.7	7.9	9.0	6.6	8.9
51 years	6.7	4.8	5.0	6.1	3.2	7.1	8.5	9.9	7.5	10.1
52 years	7.0	5.1	5.2	6.3	3.5	7.4	9.2	10.8	8.4	11.5
53 years	7.3	5.4	5.4	6.6	3.8	7.8	9.9	11.8	9.4	12.9
54 years	7.6	5.7	5.7	6.8	4.2	8.3	10.6	12.9	10.5	14.4
55 years	7.9	6.0	6.0	7.1	4.5	8.7	11.4	14.0	11.7	16.0
56 years	8.3	6.3	6.2	7.4	4.8	9.1	12.2	15.1	12.9	17.8
57 years	8.6	6.7	6.5	7.6	5.2	9.6	13.0	16.3	14.2	19.6
58 years	9.0	7.0	6.8	7.9	5.6	10.1	13.9	17.5	15.6	21.5
59 years	9.3	7.4	7.1	8.2	6.0	10.5	14.8	18.8	17.0	23.5
60 years	9.7	7.7	7.3	8.5	6.4	11.0	15.7	20.2	18.5	25.6
61 years	10.0	8.1	7.6	8.7	6.8	11.5	16.7	21.5	20.1	27.7
62 years	10.4	8.5	7.9	9.0	7.2	12.0	17.6	22.9	21.7	29.9
63 years	10.8	8.9	8.2	9.3	7.7	12.6	18.6	24.3	23.4	32.0
64 years	11.2	9.3	8.6	9.6	8.2	13.1	19.6	25.7	25.1	34.2
65 years	11.6	9.7	8.9	10.0	8.6	13.7	20.7	27.2	26.9	36.4
66 years	12.0	10.1	9.2	10.3	9.1	14.2	21.7	28.6	28.6	38.5
67 years	12.4	10.5	9.5	10.6	9.7	14.8	22.8	30.0	30.4	40.6
68 years	12.9	10.9	9.9	10.9	10.2	15.4	23.9	31.5	32.2	42.6
69 years	13.3	11.4	10.2	11.3	10.7	16.0	25.0	32.9	33.9	44.6
70 years	13.7	11.8	10.6	11.6	11.3	16.6	26.1	34.3	35.7	46.4
71 years	14.2	12.3	10.9	11.9	11.9	17.2	27.2	35.7	37.4	48.2
72 years	14.6	12.8	11.3	12.3	12.5	17.8	28.3	37.0	39.1	49.9
73 years	15.1	13.3	11.7	12.6	13.1	18.5	29.4	38.3	40.7	51.4
74 years	15.5	13.8	12.1	13.0	13.7	19.1	30.5	39.6	42.3	52.9
75 years	16.0	14.3	12.4	13.4	14.3	19.7	31.5	40.8	43.8	54.2
76 years	16.5	14.8	12.8	13.7	15.0	20.4	32.6	42.0	45.2	55.5
77 years	16.9	15.3	13.2	14.1	15.7	21.1	33.7	43.2	46.6	56.6
78 years	17.4	15.8	13.6	14.5	16.3	21.7	34.7	44.3	47.9	57.6
79 years	17.9	16.3	14.0	14.8	17.0	22.4	35.8	45.3	49.1	58.6

Male subjects
30th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	2.3	0.9	1.2	1.9	-0.1	1.4	0.1	-0.3	-0.3	-0.1
21 years	2.4	1.0	1.3	2.1	0.0	1.5	0.2	-0.2	-0.3	-0.1
22 years	2.5	1.1	1.4	2.2	0.0	1.6	0.4	-0.1	-0.2	0.0
23 years	2.7	1.2	1.5	2.3	0.1	1.8	0.5	0.0	-0.1	0.0
24 years	2.8	1.3	1.6	2.4	0.2	1.9	0.6	0.2	-0.1	0.1
25 years	3.0	1.5	1.8	2.6	0.3	2.1	0.8	0.3	0.0	0.2
26 years	3.1	1.6	1.9	2.7	0.4	2.3	0.9	0.4	0.1	0.3
27 years	3.3	1.7	2.0	2.8	0.5	2.4	1.1	0.6	0.2	0.4
28 years	3.5	1.9	2.1	3.0	0.6	2.6	1.3	0.8	0.3	0.5
29 years	3.6	2.0	2.3	3.1	0.7	2.8	1.5	0.9	0.5	0.7
30 years	3.8	2.2	2.4	3.3	0.8	3.0	1.7	1.1	0.6	0.8
31 years	4.0	2.3	2.5	3.5	1.0	3.2	1.9	1.4	0.8	1.0
32 years	4.2	2.5	2.7	3.6	1.1	3.4	2.2	1.6	1.0	1.2
33 years	4.4	2.6	2.8	3.8	1.2	3.6	2.4	1.9	1.2	1.5
34 years	4.6	2.8	3.0	4.0	1.4	3.9	2.7	2.2	1.4	1.7
35 years	4.8	3.0	3.2	4.1	1.5	4.1	3.0	2.5	1.7	2.0
36 years	5.0	3.2	3.3	4.3	1.7	4.4	3.3	2.9	2.0	2.4
37 years	5.2	3.3	3.5	4.5	1.9	4.6	3.7	3.2	2.3	2.7
38 years	5.4	3.5	3.7	4.7	2.0	4.9	4.1	3.7	2.6	3.2
39 years	5.6	3.7	3.8	4.9	2.2	5.2	4.5	4.1	3.0	3.6
40 years	5.9	4.0	4.0	5.1	2.4	5.5	4.9	4.6	3.4	4.2
41 years	6.1	4.2	4.2	5.3	2.6	5.8	5.3	5.1	3.9	4.8
42 years	6.3	4.4	4.4	5.6	2.8	6.1	5.8	5.7	4.4	5.4
43 years	6.6	4.6	4.6	5.8	3.1	6.4	6.3	6.3	5.0	6.2
44 years	6.8	4.9	4.8	6.0	3.3	6.8	6.8	7.0	5.6	7.0
45 years	7.1	5.1	5.1	6.3	3.5	7.1	7.4	7.7	6.3	7.9
46 years	7.4	5.4	5.3	6.5	3.8	7.5	8.0	8.5	7.0	8.9
47 years	7.7	5.6	5.5	6.7	4.1	7.9	8.6	9.3	7.8	10.0
48 years	7.9	5.9	5.7	7.0	4.3	8.3	9.3	10.2	8.7	11.2
49 years	8.2	6.2	6.0	7.3	4.6	8.7	10.0	11.2	9.6	12.5
50 years	8.5	6.5	6.2	7.5	4.9	9.1	10.7	12.2	10.7	13.9
51 years	8.8	6.8	6.5	7.8	5.3	9.5	11.5	13.3	11.8	15.4
52 years	9.1	7.1	6.7	8.1	5.6	10.0	12.3	14.4	12.9	17.0
53 years	9.5	7.4	7.0	8.4	5.9	10.4	13.1	15.6	14.2	18.8
54 years	9.8	7.7	7.3	8.7	6.3	10.9	14.0	16.8	15.6	20.6
55 years	10.1	8.1	7.6	9.0	6.7	11.4	14.9	18.1	17.0	22.5
56 years	10.5	8.4	7.9	9.3	7.1	11.9	15.9	19.5	18.5	24.6
57 years	10.8	8.8	8.2	9.6	7.5	12.4	16.9	20.9	20.0	26.7
58 years	11.2	9.1	8.5	9.9	7.9	13.0	17.9	22.3	21.7	28.8
59 years	11.5	9.5	8.8	10.3	8.3	13.5	18.9	23.8	23.4	31.1
60 years	11.9	9.9	9.1	10.6	8.8	14.1	20.0	25.3	25.2	33.3
61 years	12.3	10.3	9.4	11.0	9.3	14.6	21.1	26.9	27.0	35.6
62 years	12.7	10.7	9.8	11.3	9.8	15.2	22.3	28.5	28.8	37.8
63 years	13.1	11.1	10.1	11.7	10.3	15.8	23.4	30.0	30.7	40.0
64 years	13.4	11.5	10.5	12.0	10.8	16.4	24.6	31.6	32.6	42.2
65 years	13.9	12.0	10.8	12.4	11.3	17.1	25.8	33.2	34.5	44.4
66 years	14.3	12.4	11.2	12.8	11.9	17.7	27.0	34.8	36.3	46.4
67 years	14.7	12.9	11.6	13.2	12.5	18.4	28.2	36.4	38.2	48.4
68 years	15.1	13.3	11.9	13.6	13.1	19.0	29.5	37.9	40.0	50.3
69 years	15.5	13.8	12.3	14.0	13.7	19.7	30.7	39.4	41.8	52.1
70 years	16.0	14.3	12.7	14.4	14.3	20.4	31.9	40.9	43.5	53.7
71 years	16.4	14.8	13.1	14.8	15.0	21.1	33.1	42.3	45.2	55.3
72 years	16.9	15.3	13.6	15.2	15.6	21.8	34.4	43.7	46.8	56.7
73 years	17.3	15.8	14.0	15.7	16.3	22.5	35.6	45.0	48.4	58.1
74 years	17.8	16.3	14.4	16.1	17.0	23.2	36.8	46.3	49.8	59.3
75 years	18.3	16.8	14.8	16.6	17.7	24.0	37.9	47.5	51.2	60.4
76 years	18.7	17.4	15.3	17.0	18.4	24.7	39.1	48.7	52.5	61.5
77 years	19.2	17.9	15.7	17.5	19.2	25.5	40.2	49.8	53.8	62.4
78 years	19.7	18.5	16.2	17.9	19.9	26.2	41.3	50.9	54.9	63.2
79 years	20.2	19.0	16.7	18.4	20.7	27.0	42.4	51.8	56.0	64.0

Male subjects
40th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	3.7	2.4	2.4	2.9	1.2	2.4	1.5	1.3	1.2	1.2
21 years	3.9	2.5	2.5	3.0	1.3	2.6	1.6	1.4	1.3	1.3
22 years	4.0	2.6	2.6	3.1	1.4	2.7	1.8	1.5	1.4	1.3
23 years	4.2	2.7	2.7	3.3	1.5	2.9	1.9	1.7	1.5	1.4
24 years	4.3	2.9	2.8	3.4	1.6	3.0	2.1	1.8	1.6	1.5
25 years	4.5	3.0	2.9	3.5	1.7	3.2	2.2	2.0	1.7	1.6
26 years	4.6	3.1	3.0	3.7	1.8	3.4	2.4	2.1	1.9	1.8
27 years	4.8	3.3	3.2	3.8	1.9	3.6	2.6	2.3	2.0	1.9
28 years	5.0	3.4	3.3	4.0	2.0	3.7	2.8	2.5	2.2	2.0
29 years	5.1	3.5	3.4	4.1	2.1	3.9	3.0	2.8	2.4	2.2
30 years	5.3	3.7	3.6	4.3	2.3	4.2	3.2	3.0	2.6	2.4
31 years	5.5	3.9	3.7	4.5	2.4	4.4	3.5	3.3	2.8	2.7
32 years	5.7	4.0	3.9	4.7	2.5	4.6	3.8	3.6	3.1	2.9
33 years	5.9	4.2	4.0	4.8	2.7	4.9	4.1	3.9	3.4	3.2
34 years	6.1	4.4	4.2	5.0	2.8	5.1	4.4	4.3	3.7	3.5
35 years	6.3	4.6	4.3	5.2	3.0	5.4	4.7	4.7	4.0	3.9
36 years	6.6	4.8	4.5	5.4	3.2	5.7	5.1	5.1	4.4	4.3
37 years	6.8	4.9	4.7	5.6	3.3	6.0	5.5	5.5	4.8	4.8
38 years	7.0	5.2	4.9	5.8	3.5	6.3	5.9	6.0	5.2	5.3
39 years	7.3	5.4	5.1	6.1	3.7	6.6	6.3	6.6	5.7	5.9
40 years	7.5	5.6	5.3	6.3	4.0	6.9	6.8	7.2	6.3	6.6
41 years	7.8	5.8	5.5	6.5	4.2	7.3	7.3	7.8	6.9	7.3
42 years	8.0	6.1	5.7	6.8	4.4	7.6	7.8	8.5	7.5	8.1
43 years	8.3	6.3	5.9	7.0	4.7	8.0	8.4	9.2	8.2	9.0
44 years	8.5	6.5	6.1	7.3	4.9	8.4	9.0	10.0	9.0	10.0
45 years	8.8	6.8	6.4	7.6	5.2	8.8	9.7	10.9	9.8	11.1
46 years	9.1	7.1	6.6	7.8	5.5	9.2	10.4	11.8	10.7	12.4
47 years	9.4	7.4	6.9	8.1	5.8	9.7	11.1	12.7	11.7	13.7
48 years	9.7	7.6	7.1	8.4	6.1	10.2	11.8	13.8	12.7	15.1
49 years	10.0	7.9	7.4	8.7	6.4	10.6	12.7	14.9	13.8	16.7
50 years	10.3	8.2	7.6	9.0	6.7	11.1	13.5	16.0	15.0	18.4
51 years	10.7	8.6	7.9	9.4	7.1	11.7	14.4	17.2	16.3	20.2
52 years	11.0	8.9	8.2	9.7	7.5	12.2	15.3	18.5	17.6	22.1
53 years	11.3	9.2	8.5	10.0	7.9	12.8	16.3	19.8	19.0	24.1
54 years	11.7	9.6	8.8	10.4	8.3	13.3	17.3	21.2	20.5	26.2
55 years	12.0	9.9	9.1	10.7	8.7	13.9	18.4	22.7	22.1	28.4
56 years	12.4	10.3	9.5	11.1	9.1	14.5	19.4	24.2	23.7	30.7
57 years	12.8	10.7	9.8	11.5	9.6	15.2	20.6	25.7	25.4	33.0
58 years	13.2	11.0	10.1	11.9	10.1	15.8	21.7	27.3	27.1	35.4
59 years	13.6	11.4	10.5	12.3	10.6	16.5	22.9	28.9	28.9	37.8
60 years	14.0	11.8	10.8	12.7	11.1	17.2	24.2	30.5	30.7	40.1
61 years	14.4	12.3	11.2	13.1	11.6	17.9	25.4	32.1	32.6	42.5
62 years	14.8	12.7	11.6	13.5	12.2	18.6	26.7	33.8	34.4	44.8
63 years	15.2	13.1	12.0	13.9	12.8	19.3	28.0	35.5	36.3	47.0
64 years	15.6	13.6	12.4	14.4	13.4	20.1	29.3	37.1	38.2	49.2
65 years	16.1	14.0	12.8	14.8	14.0	20.9	30.7	38.7	40.0	51.3
66 years	16.5	14.5	13.2	15.3	14.6	21.7	32.0	40.4	41.9	53.3
67 years	17.0	15.0	13.6	15.8	15.3	22.5	33.4	41.9	43.7	55.1
68 years	17.4	15.5	14.1	16.3	15.9	23.3	34.7	43.5	45.4	56.9
69 years	17.9	16.0	14.5	16.8	16.6	24.1	36.1	45.0	47.1	58.5
70 years	18.3	16.5	15.0	17.3	17.4	24.9	37.4	46.5	48.8	60.0
71 years	18.8	17.0	15.4	17.8	18.1	25.8	38.7	47.9	50.4	61.4
72 years	19.3	17.6	15.9	18.3	18.8	26.7	40.0	49.2	51.9	62.7
73 years	19.8	18.1	16.4	18.8	19.6	27.5	41.3	50.5	53.3	63.9
74 years	20.3	18.6	16.9	19.4	20.4	28.4	42.6	51.8	54.7	65.0
75 years	20.8	19.2	17.4	19.9	21.2	29.3	43.8	53.0	56.0	65.9
76 years	21.3	19.8	17.9	20.5	22.0	30.2	45.0	54.1	57.2	66.8
77 years	21.9	20.4	18.4	21.0	22.9	31.1	46.2	55.1	58.4	67.6
78 years	22.4	20.9	19.0	21.6	23.7	32.0	47.3	56.1	59.4	68.3
79 years	22.9	21.5	19.5	22.2	24.6	32.9	48.4	57.1	60.4	68.9

Male subjects
50^{th} Percentile

equency [H	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	5.0	3.8	3.5	3.9	2.6	3.5	2.9	3.1	2.9	2.6
21 years	5.2	3.9	3.6	4.0	2.7	3.6	3.0	3.3	3.0	2.7
22 years	5.3	4.0	3.7	4.1	2.7	3.8	3.1	3.4	3.1	2.8
23 years	5.5	4.1	3.8	4.2	2.8	3.9	3.3	3.6	3.3	2.9
24 years	5.6	4.2	4.0	4.4	2.9	4.1	3.4	3.8	3.4	3.0
25 years	5.8	4.4	4.1	4.5	3.0	4.3	3.6	4.0	3.6	3.1
26 years	6.0	4.5	4.2	4.7	3.1	4.4	3.8	4.3	3.8	3.3
27 years	6.1	4.6	4.3	4.8	3.3	4.6	4.0	4.5	4.0	3.5
28 years	6.3	4.8	4.5	5.0	3.4	4.8	4.2	4.8	4.2	3.7
29 years	6.5	4.9	4.6	5.1	3.5	5.0	4.4	5.1	4.4	3.9
30 years	6.7	5.1	4.8	5.3	3.6	5.3	4.7	5.4	4.7	4.1
31 years	6.9	5.3	4.9	5.5	3.8	5.5	5.0	5.8	5.0	4.4
32 years	7.1	5.4	5.1	5.7	3.9	5.8	5.3	6.2	5.3	4.7
33 years	7.3	5.6	5.2	5.9	4.1	6.0	5.6	6.6	5.7	5.1
34 years	7.6	5.8	5.4	6.1	4.3	6.3	5.9	7.0	6.1	5.5
35 years	7.8	6.0	5.6	6.3	4.4	6.6	6.3	7.5	6.5	6.0
36 years	8.0	6.2	5.8	6.5	4.6	6.9	6.7	8.0	7.0	6.5
37 years	8.3	6.4	5.9	6.7	4.8	7.2	7.1	8.6	7.5	7.0
38 years	8.5	6.6	6.1	6.9	5.1	7.6	7.6	9.2	8.0	7.7
39 years	8.8	6.8	6.3	7.2	5.3	7.9	8.1	9.9	8.6	8.4
40 years	9.0	7.1	6.6	7.4	5.5	8.3	8.6	10.6	9.3	9.2
41 years	9.3	7.3	6.8	7.7	5.8	8.7	9.2	11.4	10.0	10.1
42 years	9.6	7.6	7.0	8.0	6.0	9.1	9.8	12.2	10.7	11.0
43 years	9.9	7.8	7.2	8.2	6.3	9.5	10.5	13.0	11.6	12.1
44 years	10.2	8.1	7.5	8.5	6.6	10.0	11.1	14.0	12.4	13.3
45 years	10.5	8.4	7.7	8.8	6.9	10.5	11.9	14.9	13.4	14.6
46 years	10.8	8.6	8.0	9.1	7.2	11.0	12.7	16.0	14.4	16.0
47 years	11.1	8.9	8.3	9.5	7.5	11.5	13.5	17.1	15.5	17.5
48 years	11.4	9.2	8.5	9.8	7.9	12.0	14.4	18.2	16.6	19.2
49 years	11.8	9.5	8.8	10.1	8.3	12.6	15.3	19.4	17.9	20.9
50 years	12.1	9.9	9.1	10.5	8.7	13.2	16.2	20.7	19.2	22.8
51 years	12.5	10.2	9.4	10.9	9.1	13.8	17.3	22.0	20.5	24.8
52 years	12.8	10.6	9.8	11.2	9.5	14.4	18.3	23.4	22.0	26.9
53 years	13.2	10.9	10.1	11.6	10.0	15.1	19.4	24.9	23.5	29.1
54 years	13.6	11.3	10.4	12.0	10.4	15.8	20.6	26.3	25.0	31.4
55 years	14.0	11.6	10.8	12.5	10.9	16.5	21.8	27.8	26.7	33.7
56 years	14.4	12.0	11.1	12.9	11.4	17.2	23.0	29.4	28.3	36.1
57 years	14.8	12.4	11.5	13.3	12.0	18.0	24.3	31.0	30.1	38.5
58 years	15.2	12.8	11.9	13.8	12.5	18.8	25.7	32.6	31.8	41.0
59 years	15.6	13.3	12.3	14.2	13.1	19.6	27.0	34.2	33.6	43.4
60 years	16.1	13.7	12.7	14.7	13.7	20.4	28.4	35.9	35.5	45.8
61 years	16.5	14.2	13.1	15.2	14.3	21.3	29.8	37.5	37.3	48.1
62 years	17.0	14.6	13.6	15.7	15.0	22.2	31.3	39.2	39.1	50.4
63 years	17.5	15.1	14.0	16.2	15.6	23.1	32.7	40.8	41.0	52.6
64 years	17.9	15.6	14.5	16.8	16.3	24.0	34.2	42.4	42.8	54.7
65 years	18.4	16.1	14.9	17.3	17.1	24.9	35.7	44.0	44.6	56.7
66 years	18.9	16.6	15.4	17.9	17.8	25.9	37.2	45.6	46.4	58.6
67 years	19.4	17.1	15.9	18.4	18.6	26.9	38.7	47.1	48.1	60.4
68 years	19.9	17.6	16.4	19.0	19.4	27.9	40.1	48.6	49.8	62.0
69 years	20.4	18.1	16.9	19.6	20.2	28.9	41.6	50.0	51.4	63.5
70 years	21.0	18.7	17.4	20.2	21.0	29.9	43.0	51.5	53.0	64.9
71 years	21.5	19.3	18.0	20.9	21.9	30.9	44.5	52.8	54.5	66.2
72 years	22.1	19.8	18.5	21.5	22.7	32.0	45.8	54.1	56.0	67.4
73 years	22.6	20.4	19.1	22.1	23.6	33.0	47.2	55.3	57.4	68.5
74 years	23.2	21.0	19.7	22.8	24.6	34.1	48.5	56.5	58.7	69.5
75 years	23.7	21.6	20.2	23.4	25.5	35.1	49.8	57.6	59.9	70.4
76 years	24.3	22.2	20.8	24.1	26.4	36.2	51.1	58.7	61.1	71.1
77 years	24.9	22.9	21.4	24.8	27.4	37.2	52.3	59.7	62.2	71.9
78 years	25.5	23.5	22.1	25.5	28.4	38.3	53.4	60.7	63.2	72.5
79 years	26.1	24.2	22.7	26.2	29.4	39.3	54.5	61.5	64.2	73.1

Male subjects
60th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	6.3	5.1	4.6	5.0	4.0	4.8	4.5	5.2	4.6	4.1
21 years	6.5	5.2	4.7	5.1	4.1	4.9	4.6	5.4	4.7	4.2
22 years	6.6	5.3	4.8	5.2	4.2	5.1	4.8	5.6	4.9	4.3
23 years	6.8	5.5	4.9	5.4	4.3	5.2	5.0	5.8	5.1	4.5
24 years	7.0	5.6	5.0	5.5	4.4	5.4	5.1	6.1	5.3	4.6
25 years	7.1	5.7	5.2	5.7	4.5	5.6	5.4	6.4	5.5	4.8
26 years	7.3	5.9	5.3	5.8	4.6	5.8	5.6	6.7	5.7	5.0
27 years	7.5	6.0	5.4	6.0	4.7	6.0	5.8	7.0	6.0	5.2
28 years	7.7	6.2	5.6	6.1	4.9	6.2	6.1	7.4	6.3	5.5
29 years	7.9	6.3	5.7	6.3	5.0	6.4	6.3	7.8	6.6	5.8
30 years	8.1	6.5	5.9	6.5	5.2	6.7	6.6	8.2	6.9	6.1
31 years	8.3	6.7	6.0	6.7	5.3	6.9	7.0	8.6	7.3	6.5
32 years	8.5	6.8	6.2	6.9	5.5	7.2	7.3	9.1	7.7	6.9
33 years	8.8	7.0	6.4	7.1	5.7	7.5	7.7	9.6	8.1	7.3
34 years	9.0	7.2	6.5	7.3	5.9	7.8	8.1	10.2	8.6	7.8
35 years	9.2	7.4	6.7	7.5	6.1	8.1	8.5	10.8	9.1	8.4
36 years	9.5	7.6	6.9	7.7	6.3	8.4	9.0	11.4	9.7	9.0
37 years	9.8	7.9	7.1	8.0	6.5	8.8	9.5	12.1	10.3	9.7
38 years	10.0	8.1	7.4	8.2	6.8	9.2	10.0	12.8	11.0	10.5
39 years	10.3	8.3	7.6	8.5	7.0	9.6	10.6	13.6	11.7	11.4
40 years	10.6	8.6	7.8	8.8	7.3	10.0	11.2	14.4	12.4	12.4
41 years	10.9	8.8	8.0	9.0	7.6	10.5	11.9	15.3	13.3	13.4
42 years	11.2	9.1	8.3	9.3	7.9	10.9	12.6	16.3	14.2	14.6
43 years	11.5	9.3	8.6	9.6	8.2	11.4	13.3	17.2	15.1	15.8
44 years	11.8	9.6	8.8	10.0	8.5	11.9	14.1	18.3	16.1	17.2
45 years	12.2	9.9	9.1	10.3	8.9	12.5	14.9	19.4	17.2	18.7
46 years	12.5	10.2	9.4	10.6	9.3	13.1	15.8	20.5	18.4	20.3
47 years	12.9	10.5	9.7	11.0	9.7	13.7	16.8	21.7	19.6	22.0
48 years	13.2	10.8	10.0	11.4	10.1	14.3	17.7	23.0	20.9	23.9
49 years	13.6	11.2	10.4	11.8	10.5	14.9	18.8	24.3	22.2	25.8
50 years	14.0	11.5	10.7	12.2	11.0	15.6	19.9	25.6	23.7	27.9
51 years	14.4	11.9	11.1	12.6	11.5	16.3	21.0	27.0	25.2	30.1
52 years	14.8	12.2	11.5	13.0	12.0	17.1	22.2	28.5	26.7	32.3
53 years	15.2	12.6	11.8	13.5	12.5	17.9	23.4	29.9	28.3	34.6
54 years	15.7	13.0	12.2	13.9	13.1	18.7	24.7	31.5	30.0	37.0
55 years	16.1	13.4	12.7	14.4	13.6	19.5	26.0	33.0	31.7	39.4
56 years	16.5	13.8	13.1	14.9	14.2	20.4	27.4	34.6	33.5	41.8
57 years	17.0	14.3	13.5	15.4	14.9	21.3	28.8	36.2	35.3	44.3
58 years	17.5	14.7	14.0	15.9	15.5	22.2	30.2	37.8	37.1	46.7
59 years	18.0	15.2	14.5	16.5	16.2	23.1	31.7	39.4	38.9	49.1
60 years	18.5	15.6	14.9	17.0	16.9	24.1	33.2	41.0	40.7	51.4
61 years	19.0	16.1	15.4	17.6	17.7	25.1	34.7	42.6	42.6	53.7
62 years	19.5	16.6	16.0	18.2	18.5	26.1	36.2	44.2	44.4	55.9
63 years	20.0	17.1	16.5	18.8	19.3	27.2	37.7	45.8	46.3	58.0
64 years	20.6	17.6	17.0	19.4	20.1	28.3	39.3	47.4	48.1	60.0
65 years	21.1	18.2	17.6	20.1	21.0	29.4	40.8	48.9	49.8	61.9
66 years	21.7	18.7	18.2	20.7	21.8	30.5	42.4	50.4	51.5	63.6
67 years	22.2	19.3	18.8	21.4	22.7	31.6	43.9	51.9	53.2	65.3
68 years	22.8	19.9	19.4	22.1	23.7	32.8	45.4	53.3	54.9	66.8
69 years	23.4	20.4	20.0	22.8	24.6	33.9	46.9	54.7	56.4	68.2
70 years	24.0	21.0	20.7	23.5	25.6	35.1	48.4	56.0	57.9	69.5
71 years	24.6	21.7	21.3	24.3	26.6	36.3	49.8	57.3	59.4	70.7
72 years	25.3	22.3	22.0	25.0	27.7	37.5	51.2	58.5	60.8	71.8
73 years	25.9	22.9	22.7	25.8	28.7	38.6	52.6	59.7	62.1	72.8
74 years	26.5	23.6	23.4	26.6	29.8	39.8	53.9	60.8	63.3	73.7
75 years	27.2	24.2	24.1	27.3	30.9	41.0	55.2	61.9	64.5	74.5
76 years	27.8	24.9	24.9	28.1	32.0	42.2	56.4	62.9	65.6	75.2
77 years	28.5	25.6	25.6	29.0	33.1	43.4	57.6	63.9	66.7	75.9
78 years	29.2	26.3	26.4	29.8	34.2	44.5	58.7	64.8	67.6	76.4
79 years	29.8	27.0	27.1	30.6	35.3	45.7	59.8	65.7	68.6	77.0

Male subjects
70th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	8.0	6.4	6.1	6.2	5.3	6.3	6.5	7.4	6.7	5.8
21 years	8.2	6.6	6.2	6.3	5.4	6.5	6.7	7.7	6.9	6.0
22 years	8.3	6.7	6.3	6.4	5.5	6.6	6.9	8.0	7.2	6.2
23 years	8.5	6.8	6.4	6.6	5.6	6.8	7.1	8.3	7.4	6.4
24 years	8.7	6.9	6.6	6.7	5.7	7.0	7.4	8.7	7.7	6.6
25 years	8.9	7.1	6.7	6.8	5.9	7.2	7.7	9.0	8.0	6.9
26 years	9.1	7.2	6.8	7.0	6.0	7.4	7.9	9.4	8.3	7.2
27 years	9.3	7.4	7.0	7.2	6.1	7.6	8.3	9.8	8.7	7.5
28 years	9.5	7.5	7.1	7.3	6.3	7.9	8.6	10.3	9.1	7.8
29 years	9.7	7.7	7.3	7.5	6.5	8.1	8.9	10.7	9.5	8.2
30 years	10.0	7.9	7.5	7.7	6.6	8.4	9.3	11.3	9.9	8.7
31 years	10.2	8.1	7.6	7.9	6.8	8.7	9.7	11.8	10.4	9.2
32 years	10.4	8.3	7.8	8.1	7.0	9.0	10.2	12.4	10.9	9.7
33 years	10.7	8.5	8.0	8.4	7.2	9.4	10.7	13.0	11.5	10.3
34 years	10.9	8.7	8.2	8.6	7.4	9.7	11.2	13.7	12.1	11.0
35 years	11.2	8.9	8.4	8.8	7.7	10.1	11.7	14.4	12.8	11.8
36 years	11.5	9.1	8.6	9.1	7.9	10.5	12.3	15.2	13.5	12.6
37 years	11.8	9.3	8.9	9.4	8.2	10.9	12.9	16.0	14.3	13.5
38 years	12.1	9.6	9.1	9.6	8.5	11.3	13.5	16.8	15.1	14.5
39 years	12.4	9.8	9.4	9.9	8.8	11.8	14.2	17.7	16.0	15.6
40 years	12.7	10.1	9.6	10.2	9.1	12.3	15.0	18.7	16.9	16.8
41 years	13.0	10.3	9.9	10.6	9.4	12.8	15.7	19.7	17.9	18.1
42 years	13.4	10.6	10.2	10.9	9.8	13.4	16.6	20.7	18.9	19.5
43 years	13.7	10.9	10.5	11.2	10.2	14.0	17.4	21.8	20.0	21.0
44 years	14.1	11.2	10.8	11.6	10.6	14.6	18.4	23.0	21.2	22.6
45 years	14.4	11.5	11.1	12.0	11.0	15.2	19.3	24.2	22.5	24.4
46 years	14.8	11.9	11.4	12.4	11.5	15.9	20.3	25.4	23.8	26.2
47 years	15.2	12.2	11.8	12.8	12.0	16.6	21.4	26.7	25.1	28.2
48 years	15.6	12.5	12.2	13.3	12.5	17.3	22.5	28.1	26.5	30.2
49 years	16.0	12.9	12.5	13.7	13.0	18.1	23.7	29.5	28.0	32.4
50 years	16.4	13.3	12.9	14.2	13.6	18.9	24.9	30.9	29.5	34.6
51 years	16.9	13.7	13.3	14.7	14.2	19.7	26.1	32.4	31.1	36.9
52 years	17.3	14.1	13.7	15.2	14.8	20.6	27.4	33.9	32.8	39.2
53 years	17.8	14.5	14.2	15.7	15.4	21.5	28.8	35.4	34.4	41.6
54 years	18.2	14.9	14.6	16.3	16.1	22.4	30.2	36.9	36.2	44.0
55 years	18.7	15.4	15.1	16.8	16.9	23.4	31.6	38.5	37.9	46.4
56 years	19.2	15.8	15.6	17.4	17.6	24.4	33.0	40.1	39.7	48.8
57 years	19.7	16.3	16.1	18.0	18.4	25.5	34.5	41.7	41.4	51.2
58 years	20.2	16.8	16.6	18.7	19.2	26.5	36.0	43.3	43.2	53.5
59 years	20.8	17.3	17.2	19.3	20.1	27.6	37.5	44.9	45.0	55.8
60 years	21.3	17.8	17.7	20.0	21.0	28.8	39.0	46.5	46.8	57.9
61 years	21.8	18.3	18.3	20.7	21.9	29.9	40.6	48.1	48.6	60.0
62 years	22.4	18.9	18.9	21.4	22.8	31.1	42.1	49.6	50.3	62.1
63 years	23.0	19.5	19.5	22.1	23.8	32.3	43.7	51.1	52.1	64.0
64 years	23.6	20.0	20.1	22.9	24.9	33.5	45.2	52.7	53.8	65.8
65 years	24.2	20.6	20.8	23.7	25.9	34.8	46.8	54.1	55.4	67.4
66 years	24.8	21.2	21.4	24.5	27.0	36.0	48.3	55.6	57.0	69.0
67 years	25.4	21.9	22.1	25.3	28.1	37.3	49.8	57.0	58.6	70.5
68 years	26.0	22.5	22.8	26.1	29.3	38.6	51.3	58.3	60.1	71.9
69 years	26.7	23.2	23.5	27.0	30.5	39.9	52.7	59.7	61.6	73.1
70 years	27.3	23.8	24.3	27.9	31.6	41.2	54.2	60.9	63.0	74.3
71 years	28.0	24.5	25.0	28.8	32.9	42.5	55.5	62.1	64.3	75.3
72 years	28.7	25.2	25.8	29.7	34.1	43.8	56.9	63.3	65.6	76.3
73 years	29.4	25.9	26.6	30.6	35.4	45.0	58.2	64.4	66.8	77.1
74 years	30.0	26.7	27.4	31.5	36.6	46.3	59.5	65.5	67.9	77.9
75 years	30.7	27.4	28.2	32.5	37.9	47.6	60.7	66.5	69.0	78.7
76 years	31.4	28.2	29.0	33.5	39.2	48.9	61.8	67.5	70.0	79.3
77 years	32.2	28.9	29.8	34.4	40.5	50.1	63.0	68.4	71.0	79.9
78 years	32.9	29.7	30.7	35.4	41.8	51.3	64.0	69.3	71.9	80.4
79 years	33.6	30.5	31.6	36.4	43.1	52.5	65.1	70.1	72.7	80.9

Male subjects
80th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	9.6	8.0	7.9	8.2	7.0	8.3	10.0	10.6	9.5	7.8
21 years	9.8	8.1	8.0	8.3	7.1	8.5	10.4	10.9	9.8	8.0
22 years	10.0	8.3	8.2	8.5	7.3	8.7	10.7	11.3	10.2	8.3
23 years	10.2	8.4	8.3	8.7	7.4	8.9	11.1	11.8	10.5	8.6
24 years	10.4	8.5	8.4	8.8	7.5	9.2	11.5	12.2	10.9	8.9
25 years	10.6	8.7	8.6	9.0	7.7	9.5	11.9	12.7	11.4	9.3
26 years	10.8	8.9	8.8	9.2	7.9	9.7	12.3	13.2	11.8	9.7
27 years	11.1	9.0	8.9	9.4	8.0	10.0	12.8	13.8	12.3	10.1
28 years	11.3	9.2	9.1	9.7	8.2	10.3	13.3	14.4	12.9	10.6
29 years	11.6	9.4	9.3	9.9	8.4	10.7	13.8	15.0	13.4	11.2
30 years	11.8	9.6	9.5	10.1	8.7	11.0	14.3	15.7	14.0	11.8
31 years	12.1	9.8	9.7	10.4	8.9	11.4	14.9	16.4	14.7	12.5
32 years	12.4	10.0	9.9	10.6	9.1	11.8	15.5	17.1	15.4	13.3
33 years	12.6	10.3	10.1	10.9	9.4	12.2	16.2	17.9	16.1	14.1
34 years	12.9	10.5	10.4	11.2	9.7	12.7	16.9	18.7	16.9	15.0
35 years	13.2	10.7	10.6	11.5	10.0	13.2	17.6	19.6	17.8	16.0
36 years	13.5	11.0	10.9	11.8	10.3	13.7	18.3	20.5	18.7	17.1
37 years	13.9	11.3	11.1	12.2	10.6	14.2	19.1	21.5	19.6	18.3
38 years	14.2	11.5	11.4	12.5	11.0	14.7	20.0	22.5	20.6	19.6
39 years	14.6	11.8	11.7	12.9	11.4	15.3	20.8	23.5	21.7	21.0
40 years	14.9	12.1	12.0	13.2	11.8	16.0	21.7	24.6	22.8	22.5
41 years	15.3	12.4	12.3	13.6	12.2	16.6	22.7	25.7	24.0	24.1
42 years	15.7	12.8	12.6	14.0	12.7	17.3	23.7	26.9	25.2	25.8
43 years	16.1	13.1	13.0	14.5	13.1	18.0	24.7	28.1	26.5	27.7
44 years	16.5	13.4	13.3	14.9	13.7	18.8	25.8	29.4	27.8	29.6
45 years	16.9	13.8	13.7	15.4	14.2	19.6	26.9	30.7	29.2	31.6
46 years	17.3	14.2	14.1	15.9	14.8	20.4	28.0	32.1	30.6	33.8
47 years	17.8	14.6	14.5	16.4	15.4	21.3	29.2	33.5	32.1	36.0
48 years	18.2	15.0	14.9	16.9	16.0	22.2	30.4	34.9	33.6	38.2
49 years	18.7	15.4	15.3	17.4	16.7	23.1	31.6	36.3	35.2	40.6
50 years	19.2	15.8	15.8	18.0	17.3	24.1	32.9	37.8	36.8	43.0
51 years	19.7	16.3	16.2	18.6	18.1	25.1	34.2	39.3	38.5	45.4
52 years	20.2	16.8	16.7	19.2	18.8	26.1	35.5	40.8	40.1	47.8
53 years	20.7	17.3	17.2	19.8	19.7	27.2	36.9	42.3	41.8	50.2
54 years	21.3	17.8	17.7	20.5	20.5	28.3	38.2	43.8	43.5	52.6
55 years	21.8	18.3	18.2	21.1	21.4	29.5	39.6	45.4	45.2	55.0
56 years	22.4	18.8	18.8	21.8	22.3	30.7	41.0	46.9	47.0	57.3
57 years	23.0	19.4	19.3	22.6	23.2	31.9	42.4	48.5	48.7	59.5
58 years	23.6	19.9	19.9	23.3	24.2	33.1	43.9	50.0	50.4	61.7
59 years	24.2	20.5	20.5	24.0	25.3	34.4	45.3	51.5	52.1	63.8
60 years	24.8	21.1	21.1	24.8	26.3	35.7	46.7	53.0	53.7	65.7
61 years	25.4	21.8	21.8	25.6	27.4	37.0	48.1	54.5	55.4	67.6
62 years	26.1	22.4	22.4	26.5	28.5	38.3	49.6	55.9	57.0	69.4
63 years	26.7	23.1	23.1	27.3	29.7	39.6	51.0	57.3	58.6	71.1
64 years	27.4	23.7	23.8	28.2	30.9	41.0	52.3	58.7	60.1	72.6
65 years	28.1	24.4	24.5	29.0	32.1	42.4	53.7	60.1	61.6	74.1
66 years	28.8	25.1	25.2	29.9	33.4	43.7	55.1	61.4	63.1	75.4
67 years	29.5	25.9	26.0	30.9	34.7	45.1	56.4	62.7	64.5	76.7
68 years	30.2	26.6	26.8	31.8	36.0	46.5	57.7	63.9	65.8	77.8
69 years	31.0	27.4	27.5	32.8	37.3	47.8	59.0	65.1	67.1	78.8
70 years	31.7	28.1	28.3	33.7	38.6	49.2	60.2	66.3	68.4	79.8
71 years	32.5	28.9	29.2	34.7	40.0	50.5	61.4	67.4	69.6	80.7
72 years	33.2	29.8	30.0	35.7	41.3	51.9	62.6	68.5	70.7	81.5
73 years	34.0	30.6	30.8	36.7	42.7	53.2	63.7	69.5	71.8	82.2
74 years	34.8	31.4	31.7	37.7	44.1	54.5	64.8	70.5	72.8	82.8
75 years	35.6	32.3	32.6	38.8	45.5	55.8	65.9	71.4	73.8	83.4
76 years	36.4	33.1	33.5	39.8	46.8	57.0	66.9	72.3	74.7	83.9
77 years	37.2	34.0	34.4	40.8	48.2	58.3	67.9	73.1	75.6	84.4
78 years	38.0	34.9	35.3	41.9	49.6	59.5	68.8	73.9	76.4	84.8
79 years	38.8	35.8	36.2	42.9	50.9	60.6	69.7	74.7	77.1	85.2

Male subjects
90th Percentile

Frequency [Hz]:	125	250	500	1000	1500	2000	3000	4000	6000	8000
20 years	11.7	10.1	9.9	11.0	9.6	11.7	15.1	15.7	14.1	10.1
21 years	11.9	10.3	10.0	11.2	9.8	12.0	15.6	16.3	14.6	10.5
22 years	12.1	10.4	10.2	11.5	10.0	12.4	16.1	16.9	15.2	10.9
23 years	12.4	10.6	10.4	11.7	10.2	12.8	16.7	17.5	15.8	11.4
24 years	12.6	10.8	10.6	12.0	10.5	13.2	17.2	18.2	16.4	11.9
25 years	12.9	11.0	10.8	12.2	10.7	13.6	17.9	18.9	17.1	12.4
26 years	13.1	11.2	11.0	12.5	11.0	14.1	18.5	19.6	17.8	13.1
27 years	13.4	11.5	11.2	12.8	11.3	14.5	19.2	20.4	18.5	13.8
28 years	13.7	11.7	11.5	13.1	11.6	15.0	19.9	21.2	19.3	14.5
29 years	14.0	11.9	11.7	13.4	12.0	15.6	20.7	22.1	20.2	15.4
30 years	14.3	12.2	12.0	13.8	12.3	16.2	21.4	23.0	21.0	16.3
31 years	14.7	12.4	12.2	14.1	12.7	16.8	22.2	23.9	22.0	17.3
32 years	15.0	12.7	12.5	14.5	13.1	17.4	23.1	24.9	23.0	18.5
33 years	15.4	13.0	12.8	14.9	13.5	18.1	24.0	25.9	24.0	19.7
34 years	15.7	13.3	13.1	15.3	14.0	18.8	24.9	26.9	25.1	21.0
35 years	16.1	13.6	13.5	15.7	14.4	19.5	25.8	28.0	26.2	22.5
36 years	16.5	13.9	13.8	16.1	14.9	20.3	26.8	29.1	27.4	24.0
37 years	16.9	14.3	14.1	16.6	15.5	21.1	27.9	30.3	28.6	25.7
38 years	17.3	14.6	14.5	17.0	16.0	21.9	28.9	31.5	29.9	27.5
39 years	17.8	15.0	14.9	17.5	16.6	22.8	30.0	32.7	31.2	29.4
40 years	18.2	15.4	15.3	18.0	17.3	23.7	31.1	34.0	32.6	31.4
41 years	18.7	15.7	15.7	18.6	17.9	24.7	32.3	35.3	34.0	33.6
42 years	19.1	16.2	16.2	19.1	18.6	25.7	33.4	36.6	35.4	35.8
43 years	19.6	16.6	16.6	19.7	19.3	26.7	34.6	37.9	36.9	38.1
44 years	20.2	17.0	17.1	20.3	20.1	27.8	35.9	39.3	38.4	40.5
45 years	20.7	17.5	17.6	20.9	20.9	28.9	37.1	40.7	40.0	42.9
46 years	21.2	17.9	18.1	21.5	21.7	30.1	38.4	42.1	41.5	45.4
47 years	21.8	18.4	18.6	22.1	22.6	31.3	39.7	43.5	43.1	48.0
48 years	22.4	18.9	19.2	22.8	23.5	32.5	41.0	45.0	44.7	50.5
49 years	23.0	19.5	19.7	23.5	24.5	33.7	42.4	46.4	46.4	53.0
50 years	23.6	20.0	20.3	24.2	25.5	35.0	43.7	47.9	48.0	55.5
51 years	24.2	20.6	20.9	25.0	26.5	36.3	45.1	49.3	49.6	58.0
52 years	24.8	21.2	21.6	25.7	27.6	37.7	46.4	50.8	51.3	60.4
53 years	25.5	21.8	22.2	26.5	28.7	39.0	47.8	52.2	52.9	62.7
54 years	26.2	22.4	22.9	27.3	29.8	40.4	49.2	53.7	54.5	65.0
55 years	26.9	23.0	23.6	28.1	31.0	41.8	50.5	55.1	56.1	67.1
56 years	27.6	23.7	24.3	29.0	32.2	43.2	51.9	56.5	57.7	69.2
57 years	28.3	24.3	25.1	29.9	33.5	44.7	53.2	57.9	59.2	71.1
58 years	29.0	25.0	25.8	30.7	34.7	46.1	54.6	59.3	60.8	73.0
59 years	29.8	25.7	26.6	31.6	36.0	47.5	55.9	60.6	62.2	74.7
60 years	30.6	26.5	27.4	32.6	37.4	49.0	57.2	61.9	63.7	76.3
61 years	31.3	27.2	28.3	33.5	38.7	50.4	58.5	63.2	65.1	77.8
62 years	32.1	28.0	29.1	34.5	40.1	51.9	59.8	64.5	66.5	79.1
63 years	33.0	28.8	30.0	35.4	41.5	53.3	61.0	65.7	67.8	80.4
64 years	33.8	29.6	30.9	36.4	42.9	54.7	62.3	66.9	69.1	81.5
65 years	34.6	30.4	31.8	37.4	44.3	56.1	63.5	68.0	70.4	82.6
66 years	35.5	31.2	32.7	38.5	45.7	57.4	64.6	69.2	71.5	83.6
67 years	36.3	32.1	33.6	39.5	47.1	58.8	65.8	70.2	72.7	84.4
68 years	37.2	33.0	34.6	40.5	48.6	60.1	66.9	71.3	73.8	85.2
69 years	38.1	33.9	35.6	41.6	50.0	61.4	67.9	72.3	74.8	85.9
70 years	39.0	34.8	36.6	42.7	51.4	62.7	69.0	73.2	75.8	86.6
71 years	39.9	35.7	37.6	43.7	52.8	63.9	70.0	74.2	76.8	87.2
72 years	40.8	36.6	38.6	44.8	54.3	65.1	71.0	75.0	77.7	87.7
73 years	41.7	37.5	39.6	45.9	55.6	66.3	71.9	75.9	78.5	88.2
74 years	42.6	38.5	40.7	46.9	57.0	67.4	72.8	76.7	79.3	88.6
75 years	43.6	39.5	41.7	48.0	58.4	68.5	73.7	77.5	80.1	89.0
76 years	44.5	40.4	42.8	49.1	59.7	69.6	74.5	78.2	80.8	89.3
77 years	45.4	41.4	43.9	50.2	61.0	70.6	75.3	78.9	81.5	89.6
78 years	46.4	42.4	44.9	51.3	62.3	71.6	76.1	79.5	82.2	89.9
79 years	47.3	43.4	46.0	52.3	63.5	72.6	76.8	80.2	82.8	90.1