Superior Health Council

PREVENTION, DIAGNOSIS AND THERAPY OF TINNITUS. HEALTH EFFECTS OF RECREATIONAL SOUND IN CHILDREN AND YOUNG ADULTS.

JUNE 2017
SHC № 9332

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Federal Public Service Health, Food Chain Safety and Environment

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Please cite this document as follows:
Superior Health Council. Prevention, diagnosis and therapy of tinnitus. Health effects of recreational sound in children and young adults.Brussels: SHC; 2017. Report 9332.

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ADVISORY REPORT OF THE SUPERIOR HEALTH COUNCIL No. 9332

Prevention, diagnosis and therapy of tinnitus. Health effects of recreational sound in children and young adults

This scientific advisory provides recommendations to improve care for tinnitus patients and to reduce and prevent health effects of recreational sound exposure.
With an executive summary in English, Dutch and French.

Validated by the Board in June 7, 2017[1]

EXECUTIVE SUMMARY

Advisory report of the Superior Health Council No. 9332

Prevention, diagnosis and therapy of tinnitus. Health effects of recreational sound in children and young adults

Tinnitus is a widespread phenomenon. According to the best estimates for Belgium, between ten and thirty per cent of the population experience either transient tinnitus, or even persistent tinnitus. One out of six of the patients (fifteen per cent), rate their tinnitus as very bothersome and distressing, and affecting their quality of life. Those affected perceive a sound without the presence of a sound source in their surroundings. Tinnitus is not a disease in itself, but rather a sensation that can be a symptom of an underlying disorder or dysfunction. The latter may be damage to the hearing system, impaired transfer and interpretation of the sound stimulus by the central nervous system, or a functional change of the central nervous system itself. Tinnitus may also find its origin in stress and emotion. Hearing organ damage is often induced by sound exposure, both in an occupational and a recreational setting, as well as being an effect of the aging process, an ear disease or a brain disorder.

[1] The Council reserves the right to make minor typographical amendments to this document at any time. On the other hand, amendments that alter its content are automatically included in an erratum. In this case, a new version of the advisory report is issued.

People (mainly adolescents and young adults, but also older people) who attend discotheques, concerts, and festivals or who listen to amplified music with personal music players and smartphones often experience tinnitus for shorter or longer periods of time.

These observations led the Federal Minister of Public Health to request an advisory report from the Superior Health Council (SHC) on the epidemiology and treatment of tinnitus in Belgium. In her request she explicitly refers to the need for and role of reference centres for tinnitus care. The Minister's letter also broaches the subject of hearing damage caused by sound exposure, in particular of adolescents and young adults. Within this context, reference is made to the advisory report the Council issued on personal music players in 2007. The Council is requested to provide an update of this report and to review the relevant preventive measures. This advisory report gives an answer to the questions of the Minister based on current scientific knowledge.

Improved care for people with tinnitus complaints

The SHC takes the view that giving special consideration to tinnitus care within the healthcare system is justified in view of its high prevalence, the variety of causes of tinnitus which are often of a multifactorial nature, the effect on quality of life, and the observation that current treatment modalities may have a positive impact on the complaints, without, however, curing tinnitus. The Council proposes a stepwise approach that consists of four levels, *viz.* (1) the public at large, (2) primary health care, (3) secondary health care, and (4) the centres of expertise.

The first level focuses on awareness, education and prevention. The second level is that of the general practitioner as a coordinator of primary health care. The SHC sees rooms for improvement here as regards the diagnosis of tinnitus, the assessment of the severity of the complaints, the treatment provided in collaboration with the secondary care specialists and the centres of expertise or with other medical specialists, as well as in prevention and health education. If the quality of life is more or less permanently affected, the patient should be referred to an ENT-specialist (ear-, nose- and throat-specialist), who will assess the hearing damage (third level or secondary care). The ENT-specialist will carry out a thorough examination of the nature and background of the tinnitus and the associated complaints, often in cooperation with a specialised audiologist, and will propose and plan treatment modalities. When there is no obvious effective treatment and given the complexity of many treatment modalities, consulting at the fourth level, *i.e.* the centres of expertise, may be indicated.

Thus, a multidisciplinary centre of expertise may provide support to the general practitioner and specialists in charge of the patient, or may temporarily take over the treatment. Another key function of the centre of expertise is that of coordinating research on the effectiveness and efficiency of diagnostic techniques and of treatment modalities. In the main part of this report the Council briefly reviews the evidence base underpinning acknowledged diagnostic and therapeutic approaches. A centre of expertise also plays a key role in academic, including postgraduate, education.

The SHC concludes its review of the care provided to people with tinnitus complaints with the following recommendations.

Tinnitus is an important public health issue

There is a need for research to assess and quantify the burden of tinnitus for Belgium. This study should not only focus on healthcare costs, but should also assess and quantify the burden associated with the impaired functioning of patients as well as with their increased susceptibility to other syndromes, such as depression and anxiety disorders.

Awareness and information

A monitoring programme should be developed to assess health attitudes towards tinnitus, and should target young people in particular. Such a monitoring programme may be part of the more comprehensive health monitoring efforts in Belgium.

There is a need to set up awareness raising campaigns on tinnitus and its causes aimed at the general population, but with a special focus on adolescents. Such campaigns should be repeated at regular intervals and should keep pace with changing behaviours (*e.g.* the widespread use of personal listening devices).

An assessment should be carried out to determine whether the college and university curriculum for medical doctors, audiologists, and speech therapists is up to date as regards the latest insights into the causes of tinnitus, the underlying disorders and treatment options, and, if necessary, to amend the curriculum accordingly.

Postgraduate and continued training courses should be developed and set up in order to ensure that the skills involved in tinnitus care remain up to date.

The creation of centres of expertise

The competent authorities should cooperate with scientific and professional experts in tinnitus care to develop and allow for the setting up of a network of multidisciplinary centres of expertise on tinnitus. The centres should at least encompass expertise in otorhinolaryngology, audiology, and psychology, but would preferably involve a broader range of disciplines such as neurology and psychiatry. The final stage of a stepwise approach to tinnitus care should be the involvement of an accredited centre within a network with primary and secondary healthcare professionals. The centres also provide support through scientific research and education.

The competent authorities should provide financial incentives that will make it possible for clinical research to be conducted on improved and new diagnostic tools and for treatment options to be coordinated or carried out by the centres of expertise.

Preventing hearing damage from leisure-sound exposure

The ‘soundscape’ encountered by people living in countries like Belgium has changed in recent years. Non-occupational sound exposure has been on the rise due to the increasing number of sound sources in the living environment. Traffic sound, notwithstanding its ubiquity and the nuisance it causes, is of lesser concern here, as it less significantly affects hearing. The opposite is true for noisy tools, such as lawn mowers and leaf blowers, but also for mopeds and motorbikes. A major source of exposure for young people—adolescents and young adults— are personal music players, through which high levels of sound can reach the hearing organ. Attending discotheques, concerts and festivals also exposes young people to high levels of electronically amplified sound.

The sound exposure is such that, over the years, hearing damage is likely, all the more so as the wearing of hearing protection is commonly neglected. The SHC concludes from its review of the scientific literature in the main part of this report that this concern is also warranted for Belgian adolescents and young adults. Complaints of transient tinnitus, but also of more persistent forms, are commonly reported in surveys. There is less certainty as to the extent to which hearing loss is also common, one of the reasons being that it is more difficult to investigate. Thus, sound-induced hearing loss is the result of cumulative sound exposure — both in an occupational and a recreational setting — and will therefore appear later in life. However, subtle hearing damage can be detected with more sensitive, modern techniques, which the Council already referred to in an earlier report. Such damage has been observed in some studies involving young people.

The concern raised by hearing damage from leisure-sound exposure is even more justified than at the time of the Council’s report on personal music players (2007). It also affects young children, given the increased availability of toys producing electronically amplified sound. Even though research data are scarce, the SHC points out that there are indications of increased sensitivity of the hearing organ in young children, and that this is liable to result in hearing damage later in life due to the increasing sound exposure.

Setting regulations and monitoring compliance are tools that may be used to reduce and prevent sound-related hearing damage. Current European regulations require a CE-label for products to be accepted on the European market. This implies that these products comply with European standards that have been validated by the European authorities. However, regulating sound exposures in discotheques, at concerts and at festivals is a matter of national and local authorities. The main part of this report reviews such regulations in Belgium and abroad.

In Belgium, the sound exposure at events is regulated by a Royal Decree enacted in 1977. The SHC takes the view that these regulations are inadequate for 21st century leisure-sound exposures. Regulations that are more appropriate for the present day music culture are currently in force in Flanders. Similar regulations will come into force in the Brussels Capital Region in early 2018. Only in the Walloon Region do the 1977 regulations still apply.

The Council issues the following recommendations that aim at further reducing hearing damage from leisure-sound exposure.

Increase awareness by providing information and education

The curriculum of primary and secondary education should include the consequences of sound exposure on hearing. The issues at stake are the use of personal music players, the adequate use of head phones, and the use of hearing protection.

There is a need to stimulate information campaigns and provide sources of information on the exposure to leisure-sound and its health effects. Examples are the 'Week of the sound' ('Week van de klank / La semaine du son') in Brussels and websites that offer hearing tests, such as the site of the Dutch 'Nationale hoorstichting' and 'lets Minder Is De Max' of the Flemish Government. The SHC advises that young people should be involved in these initiatives, also in a controlling capacity.

Heed should also be paid to the transient effects of sound exposure, such as temporary hearing loss, tinnitus and sound intolerance. These phenomena are to be considered as a first sign of accumulating damage and not as a 'normal' side effect of sound exposure.

Restrict sound emissions

The effectiveness of product standards should be evaluated regularly by the authorities, industry and consumer organisations. These standards are often based on occupational standards. Yet the SHC takes the view that it is by no means self-evident that the latter are also appropriate for leisure-sound exposure. The Council also notes that market access is based on prototype testing, which does not necessarily guarantee that individual products comply with the standards.

Another issue is the availability of products outside the European market. In the event of such products being sold on a large scale, the CE-marking system and the protection it provides will be undermined.

Regulate music events

From a public health perspective, adequate regulations are a necessary condition to curtail excessive sound exposure. The SHC advises the Walloon government to enact regulations that are similar to those proposed or in force in the Brussels and Flemish Regions. Although the Council supports the Brussels and Flemish regulations, it recommends to strive for a uniform, nationwide approach in order to enhance the effectiveness of the regulations.

The effectiveness of these regulations should be assessed on a regular basis. These evaluations should also take into account the progress in scientific knowledge on the relationship between hearing damage and sound exposure.

KEYWORDS

Mesh terms*	Keywords	Sleutelwoorden	Mots clés	Stichworte
Tinnitus	Tinnitus	Tinnitus	Acouphène	Tinnitus
Hearing	Hearing loss	Gehoorverlies	Perte auditive	Hörverlust
Hearing Tests	Hearing Tests	Hoortesten	Tests d'audition	Hörtests
Music	Music	Muziek	Musique	Musik
Sound	Leisure-sound	Vrijetijdsgeluid	Loisirs sonores	Freizeitlärm
Noise	Environmental noise	Omgevingslawaai	Bruit ambiant	Umgebungslärm
Quality of Life	Quality of Life	Kwaliteit van leven	Qualité de vie	Lebensqualität
Public health	Health care Centres of expertise Diagnosis Therapy	Gezondheidszorg Expertisecentra Diagnose Therapie	Soins de santé Centre d'expertise Diagnostic Thérapie	Gesundheitsversor-gung Fachzentrum Diagnose Therapie
Adolescent	Adolescent	Adolescent	Adolescent	Adoleszenten
Child	Child	Kind	Enfant	Kinder
Adult	Adult	Volwassene	Adulte	Erwachsene

* MeSH (Medical Subject Headings) is the NLM controlled vocabulary thesaurus used for indexing articles for PubMed.

CONTENTS

ABBREVIATIONS AND SYMBOLS

Abbreviations

CBT	Cognitive behavioural therapy
dB	Decibel, added to a value to denote that the quantity (in this report the sound level) is measured logarithmically (base 10)
dB(A)	Same as dB but with the sound pressure levels rated with the A-filter to approximate the sensitivity of the ear
dB(C)	Same as dB but with the sound pressure levels rated with the C-filter to approximate the sensitivity of the ear in case of loud low frequency sounds
CENELEC	European Committee for Electrotechnical Standardization
CSS	*Conseil Supérieur de la Santé* (see HGR, SHC)
ENT	Otorhinolaryngology, the medical specialty that deals with conditions of the ear, nose, and throat
EU	European Union
GR	Health Council of the Netherlands (*Gezondheidsraad*)
HCSP	*Haut Conseil de la santé publique* - France
HGR	*Hoge Gezondheidsraad* (see CSS, SHC)
Hz	hertz, SI unit of frequency
ISO	International Organization for Standardization
MP3	Music file (MPEG layer 3), MPEG is a specified digital audio or visual file format
PLD	Personal listening device, such as a personal music player or a smartphone
OAE	Otoacoustic emission
Pa	pascal, SI unit of pressure
RCT	Randomized controlled trial
rTMS	Repetitive transcranial magnetic stimulation
SHC	Superior Health Council (see CSS, HGR)
SI	International System of Units
tDCS	Transcranial direct current stimulation
TRT	Tinnitus retraining therapy
WHO	World Health Organization

Symbols

L	Sound level pressure
$L_{Aeq,T}$	A-weighted equivalent sound level over time T
L_{Amax}	A-weighted maximum sound level during a certain period; usually measured either 'Fast' (integration time 0,125 s) of 'Slow' (integration time 1 s)
$L_{EX,8h}$	A-weighted equivalent sound level at work over a 8h-working day
p	Pressure

1 INTRODUCTION AND FOCUS

This advisory report of the Superior Health Council (SHC) responds to a request of the Federal Minister of Social Affairs and Public Health. The present chapter analyses the request and provides an overview of the report.

1.1 Request

By letter dated December 17, 2015 the Federal Minister of Social Affairs and Public Health requested the SHC to prepare a report on “the management and prevention of tinnitus”. The reason given was that the international literature provided evidence that hearing disorders, including tinnitus, were a subject of concern for Belgium. The minister pointed to excessive sound exposures both in a professional and a leisure time setting. She also pointed to groups at risk, *viz*. children, adolescents and young adults. In this context she referred to the SHC advisory report on the use of digital music players (MP3) and the risk of hearing damage issued in 2007.

The minister asked the Council:

- To update and to broaden the 2007 report
- To evaluate recent epidemiological data
- To address the primary and secondary prevention and report on measures taken in other European countries
- To provide evidence based information on diagnostic and therapeutic trajectories of tinnitus patients
- To provide information on the desirability or need of reference centres *c.q.* centres of expertise for interdisciplinary treatment of tinnitus patients.

1.2 Process

After analysing the request, the Council’s Board identified the necessary fields of expertise. Subsequently an *ad hoc* working party was established; they include an interdisciplinary array of scientific and clinical competences related to tinnitus. The experts of the working party provided a general and an *ad hoc* declaration of interests and the SHC Committee on Deontology assessed the potential risks of conflicts of interest.

This advisory report is based on papers published in the international scientific literature, including reports from scientific institutions. After the report was endorsed by the working party, it was ultimately validated by the Board.

1.3 Overview of the report

The SHC interprets the minister’s request in terms of two main issues:

- The factors contributing to the incidence of tinnitus in the population and its diagnosis and treatment as well as measures to prevent its occurrence
- The short and long term impact of exposure of children, adolescents and young adults to sound (mainly popular music) on their hearing.

Although both issues are clearly related, they do not fully overlap. Exposure of youngsters to leisure-sound is associated with tinnitus. A main concern is the long term contribution to hearing loss and other forms of hearing damage including permanent tinnitus and decreased speech-in-noise recognition. When focussing on tinnitus as a sensation and possible symptom of an underlying disease or dysfunction (the first issue), apart from recreational and occupational sources of sound, also other causes and contributing factors should be reviewed in order to be able to answer the questions about prevention, diagnosis and therapy.

With respect to the second issue the SHC decided, in line with the minister's request, to focus on the exposure and effects of leisure-sound. Occupational noise exposure will not be reviewed. Also a review of the effects of environmental noise exposures such as annoyance and sleep disturbance is outside the scope of the present report. The exposure to sound of new-borns and babies is not reviewed either.[2]

It is appropriate at the outset to introduce two concepts, *i.e.* 'tinnitus' and 'sound' that will figure prominently in what follows.

Tinnitus

Tinnitus is the perception of sound in the absence of an external source (Baguley *et al* 2013, Tunkel *et al* 2014). Two forms can be distinguished: objective and subjective tinnitus (Jastreboff 1990, Møller 2007, KNO-vereniging 2016). In case of objective tinnitus the person hears a real sound that is produced within his or her own body, *e.g.* by the cardiovascular system. In the latter case—subjective tinnitus—there is a sound perception but no measureable sound. In Chapter 2 the phenomenon is discussed in more detail.

Sound and noise

Sound is the reception of air pressure waves by the hearing organ and their interpretation by the brain. The frequency of the pressure wave determines the pitch of a sound: a high-pitched tone has a squeaking sound, a low-pitched tone a humming sound. Physically, there is no distinction between sound and noise. Sound is a sensory perception and the complex pattern of sound waves with a variety of frequencies is labelled noise, music, speech *etc*. Noise can be considered as 'unwanted' sound. See Annex I for quantities related to sound.

[2] Just before this report was validated the World Health Assembly adopted a resolution on the prevention of deafness and hearing loss (WHO 2017b, a, c). The conclusions and recommendations in this report are in line with this resolution.

Contents of the report

In PART I (Chapters 2-4) the SHC reviews the state of knowledge about tinnitus and tinnitus care. First tinnitus prevalence and the various causes and contributing factors are described (Chapter 2). Chapter 0 focuses on tinnitus care which in the SHC's view should be stepwise structured following four levels (3.1). The following two sections (3.2 and 0) discuss, respectively, diagnosis and treatment including new developments. The final section (3.4) of this chapter summarises the findings. The last chapter (4) of PART I presents the Council's conclusions and recommendation for improving tinnitus care in Belgium.

PART II deals with leisure-sound exposure of young people. After a discussion of the changing soundscapes of young people (Chapter 5) and the general effects of sound exposure on hearing (Chapter 6) the following chapter (7) reviews the knowledge about exposure and effects of loud music among young people. The chapter lists data on exposure (7.1), on effects on the auditory system (7.2) and on risk awareness (7.3). Before drawing conclusions Chapter 8 summarises international and national guidance documents (8.1) as well as international and national regulations (8.2). PART II ends with conclusions and recommendations on prevention policies (Chapter 9).

The report ends with a chapter (10) with references to the cited literature, three annexes, and a chapter listing the members of the working party that prepared the report.

PART I TINNITUS: CAUSES, PREVENTION AND MANAGEMENT

This part provides information on tinnitus, its causes, prevention and management. The concise review is the basis for recommendations for public health measures and policies aiming at managing and preventing tinnitus and its underlying and contributing causes.

2 PREVALENCE AND DESCRIPTION

This chapter describes tinnitus and presents prevalence data.

2.1 Prevalence

Tinnitus affects many people for short periods of time or more chronically.[3] However, precise prevalence data are lacking. A recent review of world wide data listed figures ranging from 5 to 40 per cent (McCormack *et al* 2016). Prevalence data are commonly obtained using questionnaires to assess self-reported tinnitus. The wide range is partly explained by differences in the questions used and reflects differences in tinnitus definitions. Even in reports based on the most common type of question ('tinnitus lasting for more than five minutes at a time') prevalence figures range from 10 to 30 per cent.

The authors of a review of United States data obtained in 2007 estimated that 10 per cent of the American population had experienced tinnitus in the previous year (Bhatt *et al* 2016). Somewhat more than half of the people with tinnitus had experienced the phenomenon for five or more years. However, about three quarters of them considered tinnitus to be a small problem or not bothersome.

Even though not everyone appears to consider tinnitus as a serious health problem, others experience tinnitus as very bothersome and a seriously degrading their quality of life. This holds for one out six persons with tinnitus (fifteen per cent of the tinnitus patients). Furthermore, as will be described more extensively in PART II of this report, tinnitus is becoming more and more common among adolescents and young adults because of exposure to high to very high levels of leisure-sound from personal listening devices and attending festivals, concerts and discotheques. Apart from the impact on health and quality of life, also from a public health point of view, the impact of tinnitus is considerable and entails large societal costs. An investigation of Maastricht University, in which the University of Leuven participated, calculated the mean annual costs of tinnitus for the Netherlands to be around €7 billion of which around €2 billion was health care related (Maes *et al* 2013).[4] The healthcare costs amounted to more than 2 per cent of the total Dutch healthcare costs in 2009. Although these figures may be a factor 1.5 to 2 smaller or larger, to a large extent due to uncertain prevalence figures, one might conclude that tinnitus is a serious public health problem.

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[3] Tinnitus is also called 'un acouphène' in French and 'oorsuizen' in Dutch.

[4] Costs per patient were around €5 thousand of which €1.5 thousand is estimated to be related to health care.

The SHC deems the data listed above to be indicative for Belgium. Tinnitus is a health issue in our country that warrants further and more extensive attention, with respect to causes, as well as diagnosis and treatment. This is particularly relevant as not all causes are well known and a real cure is not available at present.

2.2 Causes and appearances of tinnitus

Tinnitus is the perception by a person of one or a variety of sounds without the presence of an external sound source (Jastreboff 1990, Baguley *et al* 2013, Tunkel *et al* 2014, KNO-vereniging 2016) (see 1.3). The name is derived from the Latin *tinnere*, which translates into 'to ring'. Tinnitus is not a disease in itself but a sensation that often points to an underlying disorder or dysfunction (Han *et al* 2009). Although prevention is important, when it occurs treatment is often required, in particular when it has a strong impact on the patient's wellbeing.

Tinnitus is called subjective when the sound is only *perceived* by the individual, *i.e.* in the absence of an (internal) sound stimulus. Patients report a great variety of sound patterns such hissing, sizzling, ringing, cracking or polyphonic, high tones or low tones, continuously present or variable in time. In objective tinnitus a physical sound is generated within the body and can be detected. Subjective tinnitus is the most common form.

In some patients tinnitus is a transient experience that disappears after days or months. When it lasts for months it is denoted as subacute and after persisting for more than half a year as chronic or persistent. Some patients barely notice the sound experience, but for others it is more bothersome and may manifest itself even as a permanent, extremely loud and incapacitating sensation. In some five per cent to a quarter of the affected population tinnitus interferes with the quality of life (Heller 2003, Krog *et al* 2010, Bhatt *et al* 2016).

Where tinnitus is a symptom of an underlying disease, it is important to treat the underlying cause rapidly. Unfortunately many causes of tinnitus are still unknown (Cima 2013, Langguth *et al* 2013). Otological causes are well accepted (Han *et al* 2009, Langguth *et al* 2013). Pathological changes along the entire auditory pathway can lead to tinnitus (Henry *et al* 2005, Han *et al* 2009, Lanting *et al* 2009, Møller *et al* 2011, Langguth *et al* 2013, Van de Heyning *et al* 2015) It can develop from initial cochlear lesions such as sudden hearing loss and hearing loss from sound exposure or from aging (see PART II for the relationship between leisure-sound exposure and tinnitus). The deterioration of hearing associated with aging (presbyacusis[5]) may lead to tinnitus. This also holds for trauma of the hearing organ from *e.g.* ototoxic drugs[6] or excessive sound pulses (firecrackers, shooting) or a disease of the auditory system. Such lesions can result in abnormal neuronal activity in central auditory pathways, which can be perceived as tinnitus.

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[5] Presbyacusis, or age-related hearing loss, is the cumulative effect of aging on hearing. It is a progressive and irreversible hearing loss resulting from degeneration of the cochlea or associated structures of the inner ear or auditory nerves.

[6] Examples are vancomycin and aminoglycosides (antibiotics), cisplatin (a chemotherapeutic drug) and furosemide (a diuretic).

Tinnitus can also be caused by abnormal changes in the auditory nerve, such as micro-vascular compression, vestibular schwannoma[7] (Langguth *et al* 2013, Lee *et al* 2015), and even multiple sclerosis (Baguley *et al* 2013). Although there is a link between hearing loss and tinnitus, the association between the two is not straightforward. Individuals with audiometrically normal hearing have been known to report tinnitus as well (Baguley *et al* 2013). On the other hand, individuals with hearing loss do not automatically develop tinnitus. Tinnitus can also be caused by an infection (*e.g.* otitis, meningitis) followed by hearing loss. It can occur as a side effect from medication either without hearing loss or accompanied by hearing loss (the ototoxic drugs mentioned above). Other factors contributing to tinnitus are head, neck, jaw and dental complaints (Henry *et al* 2005, Han *et al* 2009, Michiels *et al* 2015). However, tinnitus can also be associated with emotions, depression and burn-out (Langguth *et al* 2013, Van de Heyning *et al* 2015).

Tinnitus needs to be distinguished from auditory hallucinations as apparent in psychiatric illnesses (Johns *et al* 2002). However, music sensation may occur in tinnitus patients following acquired deafness (Griffiths 2000). In some patients tinnitus is the only or dominant symptom, whereas in others it is accompanied by complaints about the hearing or the vestibular system such as impaired hearing, distortion of sound, sensation of pressure or pain in the ear, vertigo, instability or a blurry vision. Sleep deprivation may result from tinnitus as well as anxiety and depression (Pattyn *et al* 2016). Patients also report disturbing auditory sensations with decreased sound tolerance such as hyperacusis[8] (Mertens *et al* 2016) and misophonia (Cavanna and Seri 2015). Hyperacusis patients are uncomfortable with sounds that would be acceptable for most normally hearing people. Misophonia describes the intolerance and negative reaction to a sound with a specific pattern and meaning to a given individual.

From this description it is clear that tinnitus has a large variety of causes and contributing factors, be it often with involvement of a dysfunction of the hearing organ and its coupling with the nervous system. It appears to a patient as the perception of sound, but can be accompanied by a variety of auditory and extra-auditory symptoms (*e.g.* sleep depression and anxiety), all impacting on the patient's well-being. Various causes and contributing factors have been identified, that should be assessed in diagnosis and taken into account in treatment.

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7 Schwannoma: benign tumour of nerve sheath cells

8 Hyperacusis is defined as unusual intolerance to ordinary environmental sounds (Andersson *et al* 2005). It is commonly reported in association with a range of medical conditions, including neurological deficits (*e.g.* migraine), psychiatric conditions *(e.g.* depression), and several ear, nose and throat diagnoses such as tinnitus, sound induced hearing loss, and middle ear malfunctions.

3 TINNITUS MANAGEMENT: PREVENTION, DIAGNOSIS AND THERAPY

This chapter summarizes the state of the art of tinnitus management and proposes a structure for tinnitus prevention and care.

3.1 The four levels of health care

For the organization of care for tinnitus patients, including preventing individuals becoming patients, the SHC distinguishes four levels, *viz.*

- The level of the general population, with a focus on the collectivity as well as on the individual
- Primary health care: the general practitioner
- Secondary health care: the ear-nose-throat (ENT) specialist and the specialised audiologist
- The multidisciplinary centre of expertise for advanced tinnitus care and clinical research.

This approach is schematically depicted in Figure 1 together with the main roles of each level.

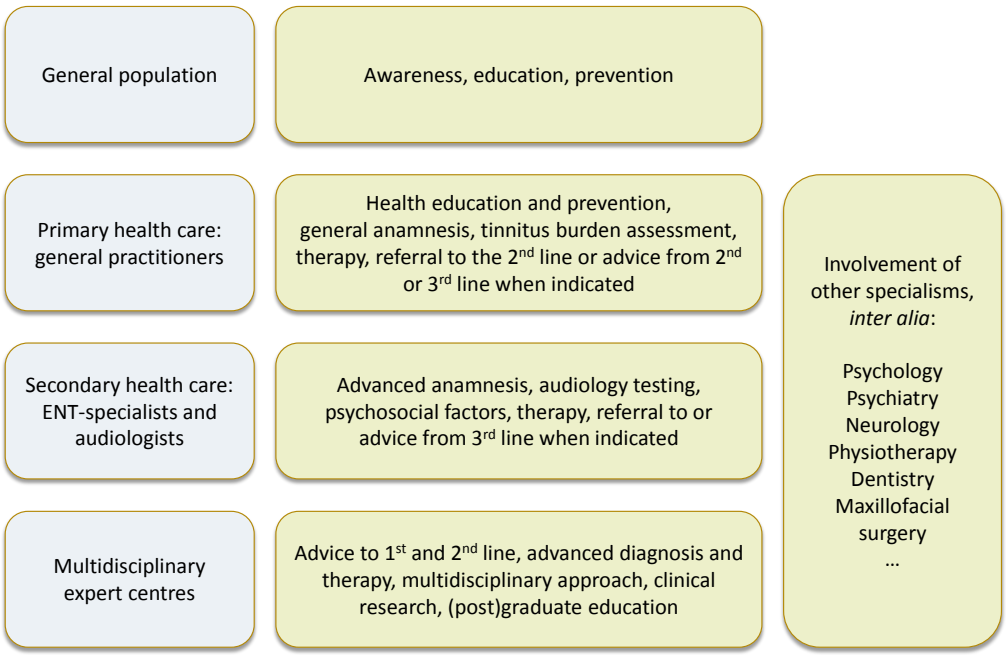

Figure 1 The four levels involved in tinnitus prevention and care.

The level of the general population

The key issues at this first level are awareness and education. People should be aware of the main causes of tinnitus, such as exposure to loud sounds and hearing impairment and ways to prevent the disorder (see also PART II of this report). But they should also be aware that tinnitus might be unrelated to sound exposure or hearing disorders, and, for example, finds its origin in excessive stress. Individuals with recurrent or persistent tinnitus should be aware of reliable information sources on their condition and its possible causes and be stimulated to contact their family doctor or another general practitioner.

Primary health care: the general practitioner

For adequate patient counselling general practitioners, such as family doctors, should be aware of the large prevalence of tinnitus (2.1) and the main causes and the ways the disorder manifests itself (2.2). They decide whether they can treat the patient and which specialists to consult or involve, if indicated outside the fields of otorhinolaryngology and audiology (*cf.* Figure 1). In this way the general practitioner functions as the coordinator of primary care and of patient education and prevention of health complaints.

Secondary health care: the ear-nose-throat (ENT) specialist and the specialised audiologist

The first task of the ENT specialist, often in cooperation with a specialised audiologist, is to assess whether the patient's complaints stem from a disorder or dysfunction of the ear or the auditory system. They are aware of factors and disorders that often accompany tinnitus and their relationship with tinnitus severity, and have knowledge of the opportunities and limitations of available therapies. They might consult other specialists (*cf.* Figure 1) or a tinnitus centre of expertise (fourth level) for further guidance or refer the patient to the centre of expertise.

The multidisciplinary centre of expertise

The centre of expertise embodies specialised knowledge about tinnitus from light to severe forms. The centre is multidisciplinary in nature including scientific expertise in the audiological, ENT and psychological fields. This characteristic is essential for diagnosis and therapy given the variety in appearances and in accompanying conditions of tinnitus and thus for supporting primary and secondary care. The centre of expertise is instrumental in coordinating and executing research on the effectiveness of diagnostic tools and therapies. It also has an important role in general and postgraduate education, and in academic and post-academic formation and teaching.

3.2 Assessment and diagnosis

The first aim of tinnitus assessment and diagnosis is to explore whether an organic pathology provoked the tinnitus. A further aim is to assess the physio-pathologic mechanism involving auditory and extra-auditory brain systems and additional factors that produce and influence the tinnitus. Finally tinnitus should be determined in terms of the degree of loudness, degree of annoyance and the impact on quality of life. The four levels discussed above (3.1 and Figure 1) also provide a stepwise framework for assessment and diagnosis.

The level of the general population

People notice whether something is out of order with their health, in this case tinnitus. However, to be able to interpret such symptoms and decide whether to consult a physician they need tools and knowledge. The key role of education was already referred to in 3.1. To be able to structure information material and assessment tools data are needed about health attitudes and health behaviour of population groups in general and of community key persons in particular. Information on hearing quality, hearing disorders and sound exposure are relevant in this respect. Policy makers should be aware that supporting such monitoring efforts is essential for developing effective information campaigns and assessments tools and for safeguarding public health and guaranteeing adequate tinnitus care. See also PART II of the present report.

Primary health care: the general practitioner

The general practitioner will assess whether the tinnitus is objective or subjective in nature and what other health and quality of life conditions might contribute to the patient's complaints. Adequate, fast tests for assessing hearing quality can be applied using a tuning fork or the so-called digits triplet test for speech-in-noise screening (Smits *et al* 2004, Van Eynde *et al* 2016). For grading tinnitus severity the 'Biesinger-test' (Figure 2) is an adequate tool (Langguth *et al* 2013). More extensive questionnaires are available, but these are more appropriate for use at the next levels. The tinnitus complaints are to be interpreted in terms of the patient's medical and health history and will be registered in his or her medical records file.

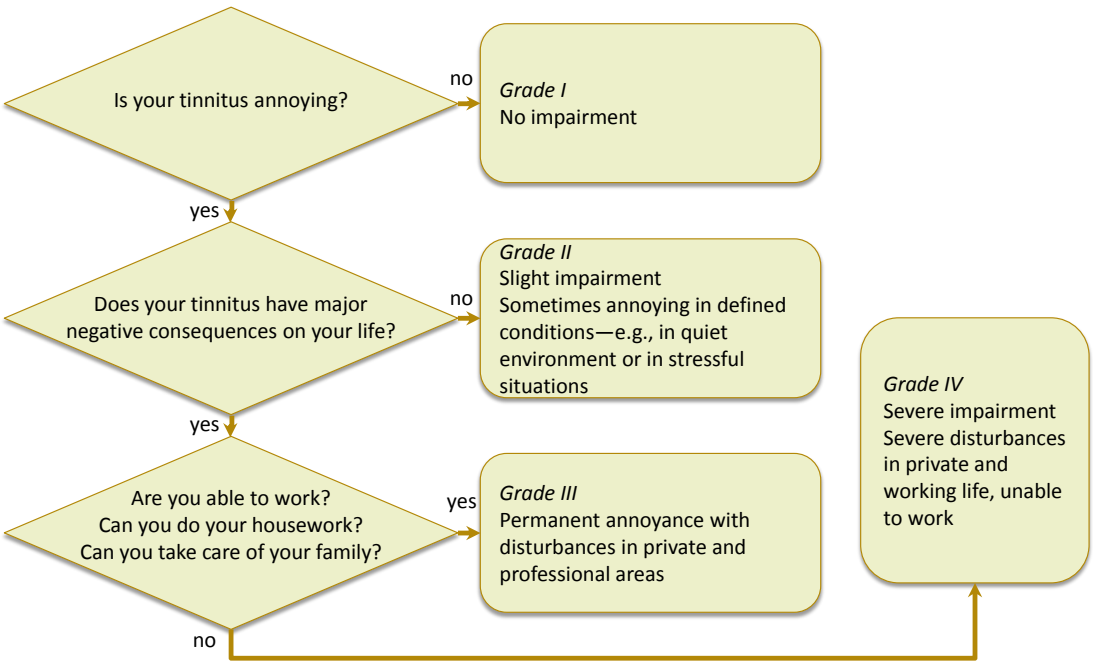

Figure 2 The 'Biesinger model' for assessing tinnitus severity. Adapted from (Langguth et al 2013).

A pointwise summary of the assessment at the general practitioner level, reads:

- *Anamnesis*: Medical history and possible tinnitus causes (sound exposure, cardiologic, vascular, and ototoxic medication, trauma, …), including questions on neck and jaw dysfunction
- *Otoscopy (examination of the ear)*: Assessment of inflammation of the middle ear (otitis media), allergies, earwax obstruction
- *Questionnaires*: Evaluation of the tinnitus burden by patient questioning (cf. Figure 2)
- General information on health attitude and tinnitus (*e.g.* prevention of exposure to loud sound).

Secondary health care: the ear-nose-throat (ENT) specialist and the specialised audiologist

The general practitioner will discuss with the patient whether referral to a specialist (secondary care or third level) is appropriate. At this level a more extensive assessment of the patient's complaints and his or her aetiology will be performed by the ENT-specialist, often in cooperation with a specialised audiologist. The assessment starts with a comprehensive otological examination. This report is not the place to discuss diagnostic models in detail. The SHC refers to an American clinical practice guideline (Tunkel *et al* 2014) and to a flow chart proposed by the Tinnitus Research Initiative (Biesinger *et al* 2009) (see also Annex III (Langguth *et al* 2007)).

These approaches include audiological and otological assessments and severity assessment with psycho-acoustic tests (Meikle *et al* 2008) and validated questionnaires, such as the Tinnitus Functional Index, the Tinnitus Handicap Inventory and the Tinnitus Questionnaire (McCombe *et al* 2001, Meikle *et al* 2012, Henry *et al* 2016).

A pointwise summary of the assessment at the specialist level, reads:

- *Anamnesis*: General medical history, otological history, subjective hearing loss, vertigo (sensation of movement of objects around a person), otalgia (ear pain), cervicogenic problems (problems related to the neck), neck and jaw dysfunction; more extensive evaluation of tinnitus characteristics: duration (acute, subacute, chronic), type (noise, tone, polyphonic), location in the brain (unilateral, bilateral, central), pulsatile or non-pulsatile; possible causes
- *ENT examination, including otomicroscopy*
- *Basic audiological testing*: tonal audiometry, impedance measurements, speech-in-quiet, otoacoustic emissions (OAEs)[9]
- *Concomitant factors*: use of validated questionnaires for assessing depression, anxiety, sleep deprivation, hyperacusis …
- *Imaging* (*e.g.* magnetic resonance imaging) if indicated using otological criteria
- *Tinnitus severity*: use of validated questionnaires to evaluate the tinnitus burden

The multidisciplinary centre of expertise

As mentioned above (3.1) the centre of expertise will support the general practitioner and the secondary care specialists in interpreting that patient's data, or it will receive the patient for more advanced assessment. Advanced diagnostic tools include imaging techniques and advanced audiological testing. The imaging techniques encompass magnetic resonance imaging, computerized tomography, positron-emission tomography and recording quantitative electro-encephalograms. Examples of advanced audiological testing are tonal audiometry including high frequencies, speech-in-noise testing, detailed tinnitus analysis, OAEs, auditory brain stem responses, event-related potentials[10], and electro-cochleography. Another issue is demystifying beliefs about tinnitus, as dysfunctional beliefs may impair the patient's quality of life (Cima *et al* 2011). Essential is the multidisciplinary approach by a team of experts including the secondary care specialists, but also including otology-neurotology physicians, audiologists, speech therapists, physiotherapists, clinical psychologists, and psychiatrists.

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[9] Otoacoustic emissions (OAEs) are sounds given off by the inner ear when the cochlea is stimulated by a sound. They can be measured with a small probe inserted into the ear canal. People with normal hearing produce these emissions.

[10] An event-related potential is an electrophysiological response of the brain by environmental stimuli. They are measured by means of electroencephalography.

3.3 Treatment modalities

Also in treatment a stepwise approach from second to fourth level (*cf.* Figure 1: primary care, secondary care, centre of expertise) should be followed. In primary care the treatment of underlying diseases is usually restricted, apart from counselling, to pharmacotherapy for acute cases. Patients with recurrent and persistent tinnitus are treated by the secondary care specialists and the multidisciplinary teams of the centres of expertise following referral by the general practitioner.

General

Even though tinnitus is a symptom and not a disease, coping with and treatment of the symptom is important using a holistic approach. If its underlying cause is curable, this should be attempted for. For example, if an objective tinnitus, such as pulsatile tinnitus, is caused by an organic lesion, the treatment focuses on curing the cause. Similarly, if a low pitch tinnitus is present because of otosclerosis[11], a surgical treatment can resolve the tinnitus complaint (Ismi *et al* 2017). The decrease in tinnitus is most often related to the degree of success of the air-bone gap closure after the surgery. Comorbidities like depression, should be treatment with pharmacological support, if necessary, and neck problems with chronic pain with pain therapy.

Acute tinnitus

Acute tinnitus, with an onset shorter than four weeks, together with acute hearing loss can often be regarded as a symptom of an inner ear disease and should therefore be diagnosed by proper audiometry and treated as soon as possible, preferably within a week (Levie *et al* 2007). Administration of corticosteroids can be a first choice, either intravenously or orally in case of cochlear damage. Recently the use of intratympanic corticosteroids[12] was advocated (Barreto *et al* 2016). In selected cases hyperbaric oxygen can be administered.

Rather than attacking the cause, most of the pharmacotherapy focuses on reducing the tinnitus severity. Unfortunately, pharmacotherapy has not been demonstrated to provide a long-term reduction of tinnitus in excess of placebo effects (Langguth *et al* 2013). However, new medications are currently under study (for a review see (Kingwell 2016)).

Subacute and chronic tinnitus

Until recently, evidence for successful treatment of tinnitus was limited. Present practices for tinnitus care consist primarily of fragmented interventions, which often result in telling patients that nothing can be done about their disorder and that they should learn to live with it (Cima *et al* 2009, Cima *et al* 2012). A pharmacological cure for chronic tinnitus is unavailable (Langguth and Elgoyhen 2012), be it that promising results from experimental studies with specific patients need further confirmation. However, other effective interventional options for tinnitus do exist.

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[11] Otosclerosis is an abnormal bone growth near the stapes and the cochlea or inner ear.

[12] Intratympanic corticosteroids: injection of corticosteroids in the middle ear.

Tinnitus retraining therapy and cognitive behavioural therapy

In general, there are two overlapping intervention approaches. The first consists of applying sound-based therapies, such as tinnitus retraining therapy (TRT). TRT involves mixing of the tinnitus with a broadband noise at the sound perception level in combination with structured counselling sessions. The approach aims to ameliorate tinnitus distress through education and exposure to a neutral external sound. Through habituation patients are expected to be less annoyed by their tinnitus. Supporting evidence for this approach and in particular for TRT is scarce, and most published reports derive from retrospective and uncontrolled trials. A Cochrane[13] review identified one randomized controlled trial (RCT) that suggests that TRT is much more effective than simple tinnitus masking (Phillips and McFerran 2010). However, due to methodological weaknesses of this study, further research is required to assess the value of TRT and its effect on patients' tinnitus severity scores and quality of life. The SHC wants to underline that this finding does not contradict the observation that some patients may benefit from TRT.

The other main approach is cognitive behavioural therapy (CBT). On the basis of the outcomes of eight trials the authors of a Cochrane review concluded that that CBT has a positive impact on the quality of life of the tinnitus patients and lowers depression scores (Martinez-Devesa *et al* 2010). The subjective loudness of the tinnitus appeared not to be affected by the treatment. CBT is a comprehensive form of psychotherapy aimed at modifying dysfunctional beliefs and behaviours. Typically, CBT includes psycho-education, relaxation, exposure techniques, and behavioural reactivation, often in combination with mindfulness-based training. Many insights on its effectiveness have been gained from evidence-based treatment of pain. To further assess the value of CBT-modalities for tinnitus treatment large scale and well controlled trials are needed.

Research into improved forms of CBT treatment is ongoing. The SHC highlights a multidisciplinary protocol for tinnitus treatment (Cima *et al* 2012). This protocol encompasses a stepped-care CBT approach with elements of TRT. It was validated in a RCT with nearly 500 patients in total. Stepped-care allows organising health services on the basis of the individual needs of a patient, with a gradual increase in the intensity of care at each level. The step-wise treatment appeared to be much more effective than the standard level of tinnitus care, and to significantly improve the patients' quality of life. No side-effects of the stepped-care CBT approach were reported in this study.

Other approaches to tinnitus treatment

The effect of electrical stimulation of the cochlea has been studied for some time. It is expected to fully suppress tinnitus perception or at least temporarily cancelling the sound perception.

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[13] Cochrane "[is] a global independent network of researchers, professionals, patients, carers, and people interested in health. Cochrane contributors - 37,000 from more than 130 countries - work together to produce credible, accessible health information that is free from commercial sponsorship and other conflicts of interest. […] Cochrane's contributors are affiliated to the organization through Cochrane groups: healthcare subject-related review groups, thematic networks, groups concerned with the methodology of systematic reviews, and regional centres" (http://www.cochrane.org/, accessed 12-05-2017).

High pulse rate electrical stimulation restores spontaneous-like patterns of spike activity in the auditory nerve that might explain the suppression effect (Rubinstein *et al* 2003, Han *et al* 2009). Cochlear implants have therefore been promoted as an effective way to compensate for hearing loss and tinnitus symptoms associated with the hearing loss (Van de Heyning *et al* 2008). A systematic review and meta-analysis of three case series studies concluded that cochlear implants favourably affect the severity of tinnitus, also in single-sided deafness patients (Blasco and Redleaf 2014). All patients felt that they localized sound better, and most felt that they understood speech better. These results are considered promising, also for single-sided deaf patients with proper motivation. Further studies are necessary to confirm these effects and to compare the success of hearing rehabilitation of cochlear implants and traditional modalities such as contralateral routing of signal and bone-anchored hearing aids. No comparative data is available on quality of life or on side effects in patients treated with cochlear implantation. Ten year follow-up studies showed lasting benefits on tinnitus and auditory capabilities for cochlear implant patients with very selective inclusion criteria (Mertens *et al* 2016, 2017).

Sound enrichment or sound improvement has been proposed as a part of treatment of tinnitus. It may consists of hearing aids adjustment with or without tinnitus noise masking with the aim to result in a relief from tinnitus and improving communication. A Cochrane review concluded on the basis of two relatively small RCTs that a favourable effect on tinnitus severity was observed with this treatment approach (Hobson *et al* 2012). However, the evidence was rated as rather weak, which does not necessarily imply that the therapy is without merit. No comparative data on quality of life or on side effects in patients treated with sound enrichment therapy have been reported.

Further developments

New pathophysiological insights have prompted the development of innovative brain-based treatment approaches to directly target the neuronal correlates of tinnitus (Langguth *et al* 2013). Repetitive transcranial magnetic stimulation (rTMS) is a non-invasive neuromodulation technique. It envisages to modulate certain hyperactive cerebral regions causing tinnitus to diminish their activity by inducing electrical currents in the brain. A Cochrane report concluded that there is little support for the use of rTMS in tinnitus patients (Meng *et al* 2011). Improvements on patients' quality of life and tinnitus loudness were observed, but are not very robust given the small size and methodological weaknesses of the studies. rTMS appears to be a safe treatment for tinnitus in the short-term, but data on long-term safety are lacking. Further research is needed to confirm the effectiveness of rTMS for tinnitus patients, be it that several centres have abandoned this treatment option.

Finally, tinnitus treatment based on transcranial direct current stimulation (tDCS) was recently reviewed (Song *et al* 2012). An improvement in tinnitus severity was observed. This approach was labelled as promising by the authors, but more research is needed to examine the effect on tinnitus severity, quality of life and safety at long-term (Lefaucheur *et al* 2017, Zenner *et al* 2017).

3.4 Synthesis

From the concise review above the SHC concludes that for subacute and chronic tinnitus there is increasing evidence to support both the efficacy and cost-effectiveness of the multidisciplinary CBT treatment incorporating elements of TRT. This approach is indicated for mild to severe tinnitus. This treatment for tinnitus patients is not to be confused with general CBT, as it should be directed specifically to the tinnitus experience.

The SHC notes that TRT is offered by commercial hearing centres often in combination with sound enrichment therapy. It requires lasting treatment adherence of the patient. Although there is evidence supporting this therapy modality, it remains unclear whether TRT actually decreases the tinnitus complaints. However, it can be beneficial for some highly motivated patients with moderate to severe tinnitus, if performed by highly experienced practitioners.

The SHC highlights the rehabilitation with cochlear implants of single-sided deafness with increasing international evidence showing a clear benefit regarding hearing and tinnitus in selected patients.

As mentioned above research is ongoing and the therapeutic arsenal will certainly be extended in the coming years. The SHC supports the stepped-care approach with the involvement of various disciplines. This might also avoid ‘medical shopping’ by patients after disappointing experiences with some treatments.

4 IMPROVING TINNITUS CARE IN BELGIUM

This final chapter of PART I presents recommendations for improving tinnitus care in our country.

Recognizing tinnitus as a serious public health issue

The data reviewed above provide evidence for the societal importance of tinnitus. It is a widespread disorder that negatively impacts on the quality of life. Not only is this a handicap for the individual, but tinnitus also represents a collective burden. Unfortunately data on the magnitude and components of the societal burden are scarce and are lacking for Belgium.

Therefore the SHC recommends that:

There is a need for research to assess and quantify the burden of tinnitus for Belgium. This study should not only focus on healthcare costs, but should also assess and quantify the burden associated with the impaired functioning of patients as well as with their increased susceptibility to other syndromes, such as depression and anxiety disorders.

Fostering awareness and education

Improved tinnitus care starts with prevention. The basis for prevention is awareness and education of the general population about the disorder, as well as of general practitioners in their role as primary care patient counsellors. Efforts to stimulate awareness and to structure education need to be based on information about health attitudes in relation to the possible causes of the disorder. Therefore the SHC recommends:

A monitoring programme should be developed to assess health attitudes towards tinnitus, and should target young people in particular. Such a monitoring programme may be part of the more comprehensive health monitoring efforts in Belgium.

There is a need to set up awareness raising campaigns on tinnitus and its causes aimed at the general population, but with a special focus on adolescents. Such campaigns should be repeated at regular intervals and should keep pace with changing behaviours (*e.g.* the widespread use of personal listening devices).

An assessment should be carried out to determine whether the college and university curriculum for medical doctors, audiologists, and speech therapists is up to date as regards the latest insights into the causes of tinnitus, the underlying disorders and treatment options, and, if necessary, to amend the curriculum accordingly.

Postgraduate and continued training courses should be developed and set up in order to ensure that the skills involved in tinnitus care remain up to date.

Enabling tinnitus centres of expertise

Tinnitus is a multifactorial disorder and in most cases a symptom of an underlying disease. Causes vary, as well as severity. At present a real cure is lacking and therapies are, apart from treating underlying diseases, directed at compensating the perception of the tinnitus sound and thus improve a patient's quality of life. A multidisciplinary approach is therefore required to assess and treat the disorder in (the many) complicated cases. Above a structure of tinnitus care was described in which centres of expertise provide support to general practitioners and secondary care specialists or assess and treat patients with advanced techniques. A further task of the expert centre is the coordination of research into newer or improved diagnostic tools and treatments and providing graduate and postgraduate courses.

The SHC therefore recommends:

The competent authorities should cooperate with scientific and professional experts in tinnitus care to develop and allow for the setting up of a network of multidisciplinary centres of expertise on tinnitus. The centres should at least encompass expertise in otorhinolaryngology, audiology, and psychology, but would preferably involve a broader range of disciplines such as neurology and psychiatry. The final stage of a stepwise approach to tinnitus care should be the involvement of an accredited centre within a network with primary and secondary healthcare professionals. The centres also provide support through scientific research and education.

The competent authorities should provide financial incentives that will make it possible for clinical research to be conducted on improved and new diagnostic tools and for treatment options to be coordinated or carried out by the centres of expertise.

PART II LEISURE-SOUND EXPOSURE OF YOUNG PEOPLE: EFFECTS ON THEIR HEARING

The ubiquitous nature of leisure-sound exposure is a phenomenon of the second half of the 20th century and the present one. In particular young people are exposed. This part discusses data on their exposures and the possible effect on their hearing, including tinnitus. The necessity and effectiveness of preventive measures are discussed and recommendations for public health policies are formulated.

5 SOUNDSCAPE OF YOUNG PEOPLE

Sound is an essential feature of living. Natural phenomena like wind, rain, waves, *etc*. are accompanied by sound as are various human daily activities. The perception of sounds determines our actions, *e.g*. as a warning for imminent danger or by evoking joyful emotions. So sounds derive their meaning from the interpretation by people and this interpretation may differ from one person to another.[14]

The term 'soundscape' was introduced in the 1970s to describe the dynamical sound environment people experience (Schafer 1993). The historical and cultural analysis of soundscapes aims at furthering the harmony between people and their living environment. Although soundscape is not a well-defined entity, it refers to the acoustic environment but within a context which is shaped by all sensory stimulations and by the knowledge people have acquired (Botteldooren *et al* 2013 p36). Even though in recent years soundscape research focuses on the outdoor environment (COST 2013), its original meaning was broader (Schafer 1993), and does not only include sounds in the outdoor environment, but also from private listening to music (Pinch and Bijsterveld 2004 p643).

The focus here is the soundscape of young people, between 12 and 30 years of age, *i.e.* adolescents and young adults. An important part of their soundscape consists of exposure to popular music using personal listening devices (PLDs), and during visits to bars, discotheques, concerts and festivals. Especially in the present decade the possibility of music listening practically always and everywhere through personal music players, smartphones and streaming services has affected the soundscape of young people, but also that of older people, tremendously. According to a 2014 survey 93% of the United States population listens more than 25 hours a week to music, and increasingly through streaming services (Nielsen 2015). Sales of wireless listening devices are expected to increase (GFK 2016).

An extensive survey in Great Britain and the United States revealed that two thirds of the respondents felt passionately about music or that music was at least as important as other leisure activities (Bonneville-Roussy *et al* 2013). The importance of music in life diminished with increasing age: three quarters of the 13 year old respondents felt music to be important to very important in contrast to half of the 65 year olds (which is still a considerable fraction).

[14] An example: the sounds of an open air pop concert may be enjoyed by the attendees (music) but disliked by people living nearby (noise).

The importance was reflected in the average hours per week of music listening: from a maximum of 25 hours for 18 year old to a minimum of 12 hours for the 58 year old.[15] The SHC cannot think of arguments for corresponding data for Belgian youth and adults to be drastically different. However, it would interesting to obtain more precise data by analysing the time-use surveys of Statistics Belgium and the Research Group TOR of the Vrije Universiteit Brussel.[16]

A second internet survey by the same British research group with a quarter of million respondents revealed preferences for types of music as a function of age and personality traits (Bonneville-Roussy *et al* 2013). They distinguish five types of music on the basis of sound related attributes, psychological attributes and genres (Rentfrow *et al* 2011). During adolescence preferences are highest for what the authors denote as 'intense' (loud, percussive music, genres such as rock and heavy metal) and 'contemporary' (electric, percussive music, genres such as rap and soul). With increasing age preferences shift to music types as 'unpretentious' (relaxing music, genres such as pop and country) and 'sophisticated' (instrumental music, genres such as blues, jazz and classical). The authors interpret these trends in terms of psychological characteristics related to adolescence and changes in such characteristics with increasing age. These data are relevant to tailor and target information campaigns related to related to leisure-sound exposure and the risk of hearing impairment.

6 SOUND EXPOSURE AND EFFECTS IN YOUNG CHILDREN

As mentioned above, the focus of this report is on leisure-sound exposure and its effects in adolescents and young adults. However, as the request for advice also refers to children, this chapter reviews the scarce data (van Kamp and Davies 2013) on exposure and its effects among children from 4 to 12 years old. It is based on the results of an European project published in 2001 (Bistrup 2001, Passchier-Vermeer *et al* 2001, Bistrup 2003) and of a more recent European project published in 2006 (Bistrup *et al* 2006). Exposure data are summarized in Table 1.

Like all of us, children are exposed to environmental sound from traffic (road, rail and air) and from industry, as well as from sources inside the home. In affluent societies the sound levels are generally such that hearing impairment is not expected from these exposures.[17] An exception might be the noise from tools or equipment used inside or outside the house such as power drills and lawnmowers with recorded sound exposure levels of 80 to 100 dB(A), and the noise from low-flying military aircraft.

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15 Responses were recorded in 2009 and obtained from an internet panel of 9000 people recruited by a global marketing research company (Bonneville-Roussy *et al* 2013).

16 http://www.time-use.be/en/, accessed 12-05-2017. In the time-surveys only around 5 percent of the respondents register to engage in 'music listening' and that for around 7 hours per week (2013). However, respondents also engage in leisure time activities as 'recreation, 'going out', *etc.* where they may also experience music.

17 The main health effects of environmental noise exposure are annoyance, sleep disturbance and cardiovascular effects. The Council reviewed these effects in its reports on the health effects of traffic (Hoge Gezondheidsraad 2011) and on the health effects of wind turbines (Superior Health Council 2013).

A particular sound exposure of children is due to toys, such as music boxes, toy mobile phones and cap guns and pistols. Peak exposure levels vary from 79 dB(A) for the music box to 134 dB(A) for the cap gun. When many children play together, as is the case in kindergartens or after-school centres, Danish data indicate that levels may exceed 80 dB(A) during the course of the day and in some cases 85 dB(A).

Table 1 Sound exposure levels of children at various locations and from various sources. Adapted from (Bistrup 2001)[18]

Location or source	Sound exposure level in dB(A)			
The home	range	61	-	75
Tools and equipment	range	78	-	102
Hospitals	often exceeding			70
Day care institutions	up to	75	-	81
Toys	range	79	-	134
Firecrackers	up to			150
Schools		47	-	77
After-school clubs				85
Transport in cities		74	-	82

The high sound emissions of some toys and equipment, as summarily reviewed above, may impair the hearing of children. Sources of concern are: noisy toys, firecrackers, tractors and other agricultural machines, shooting equipment, power tools, musical instruments and personal audio equipment. Although hearing impairment such as hearing loss and tinnitus has been reported in isolated cases, the results of large-scale hearing surveys among schoolchildren fail to show increases in hearing impairment attributable to sound exposure. An exception may be exposure to noise from extreme low-flying aircraft that was found to induce hearing loss and tinnitus in children (Ising *et al* 1990). There is more evidence for non-auditory effects of sound exposure in children, such as annoyance, effects on blood pressure and effects on cognition, but these are outside the scope of the present report.

Whether the hearing organ of children is more susceptible to impairment from sound exposure is debated in the literature. The various views differ with the endpoint considered and depend on the interpretation of animal studies. A British review prepared for deriving standards for toys concluded “Apart from neonates, there is no compelling body of evidence to suggest that infants and children are more susceptible than adults to noise-induced hearing loss” (Lower *et al* 1997). But what sound exposure at a young age means for hearing at later ages is unknown. The surveys mentioned above are generally unable to detect subtle damage that may have an impact later in life. Animal experiments may be interpreted in terms of higher susceptibility at young ages (Lower *et al* 1997, Passchier-Vermeer *et al* 2001, Kujawa and Liberman 2006, McLaren *et al* 2014). Also effects on cognition from classroom noise are mentioned and considered to be an argument for stricter exposures standards than for adults at work (McLaren *et al* 2014).

[18] Including data from (Passchier-Vermeer 1989).

7 LOUD MUSIC AND ADOLESCENTS AND YOUNG ADULTS

This chapter further details the information on leisure-sound exposure of young people referred to in Chapter 5. Subsequently data are presented on the effects of these exposures.

7.1 Exposure

Amplified music is a dominant source of the soundscape of young people during leisure time as compared with sound from activities such as attending or participating in (motor) sport events, shooting firearms, use of fireworks, and use of noisy toys (Biassoni *et al* 2005). Watching movies or plays and using noisy tools are also an important part of present day soundscapes (Jokitulppo and Bjork 2002, Keppler *et al* 2015b, Degeest *et al* 2017b). Music sound exposure can be categorized into using PLDs, attendance at nightclubs and discotheques, attendance at live concerts, listening to home stereo's, and playing a musical instrument, playing in a band or in an orchestra (Medical Research Council Institute of Hearing Research 1986, Passchier-Vermeer 1989, Clark 1991, Jokitulppo *et al* 2006, Keppler *et al* 2015b).

There is a large variation in duration of use, listening time in hours per week, and listening levels of PLDs reported within and between studies. However, tendencies are that females spend less time listening to PLDs, and listen to less intense levels than males (Smith *et al* 2000, Williams 2005, Torre 2008, McNeill *et al* 2010). The use of PLDs tends to change during lifetime with a higher proportion of adolescents using PLDs more frequently than young adults (Smith *et al* 2000, Maassen *et al* 2001, Wittman and Scott 2006). Maximum sound exposure levels of PLDs range from 97 dB(A) for earbuds to 103 dB(A) for supra-aural headphones (Keppler 2010). Preferred listening levels are lower for over-the-ear headphones as compared to earbuds (Hodgetts *et al* 2007), but these levels are also dependent on the presence of background noise, type of music and type of PLD (Fligor and Cox 2004, Williams 2005, Hodgetts *et al* 2007, EU Scientific Committee on Emerging and Newly Identified Health Risks 2008, Keith *et al* 2008, Vogel *et al* 2011, Jiang *et al* 2016).

Music venues such as nightclubs, discotheques, concerts or festivals are attended more frequently by males and young adults as compared to females and adolescents (Meyer-Bisch 1996, Maassen *et al* 2001, Meecham and Hume 2001). Sound exposure levels can amount up to 105 dB(A) for concerts (Mercier *et al* 2003, Ryberg 2009) and up to 112 dB(A) for clubs (Sadhra *et al* 2002, Bray *et al* 2004, Santos *et al* 2007, Twardella *et al* 2008).

Belgian data

Up to now, studies in Belgium are limited to the Flanders Region. For Flemish young adults aged between 18 and 30 years, the time spent per week or month, the total time of exposure in years, and the self-estimated loudness for several leisure noise activities were used to calculate the weekly and lifetime equivalent sound exposures in recent research of Ghent University. Notwithstanding the current popularity of PLDs, its relative contribution in weekly and lifetime equivalent sound exposures was considerable less than for activities as visiting nightclubs or pubs, attending musical concerts or festivals, and playing in a band or orchestra (Keppler *et al* 2015b, Degeest *et al* 2017a, Degeest *et al* 2017b). Data from this study are presented in Table 2. The exposure levels are normalized tot a 40-hours week to make them comparable with data on occupational exposure (cf. Annex I). As such, a large proportion of adolescents and young adults using PLDs and attending music venues are at risk of developing sound-induced hearing problems (Jiang *et al* 2016, le Clercq *et al* 2016).

Table 2 Data on exposure to leisure time sound of 517 Flemish people (age 18-30 years). Data have been rounded. Sound exposure presented as $L_{Aeq,40hweek}$ with the standard deviation within brackets. Adapted from (Degeest et al 2017a, Degeest et al 2017b).

Activity	**Attendance**	**Average period**	**Equivalent sound level (40h week)**
	%	**year**	**dB(A)**
Watching movies or plays	96	10	50 (8.5)
Visiting nightclubs or music venues	93	6	74 (10.5)
Attending musical concerts or festivals	86	6	65 (8.9)
Listening to PLDs through headphones	85	7	58 (12.2)
Listening to a home stereo or radio	69	10	58 (8.8)
Attending sport events	50	8	52 (9.7)
Using noisy tools	28	6	62(13.7)
Practicing a musical instrument	27	10	56 (11.7)
Playing in a band or orchestra	13	6	66 (10.5)
Other noisy leisure-time activities	10	6	67 (10.5)

7.2 Effects on the auditory system

Given the exposure levels obtained in a multitude of studies, in particular the younger generation is at risk to develop sound-induced symptoms such as hearing loss, hyperacusis[19] and tinnitus (Smith *et al* 2000, Gilles *et al* 2013, Jiang *et al* 2016). An overview of data on temporary and permanent tinnitus related to leisure-sound exposure are presented in Figure 3.

[19] See Footnote 8, p26.

Below data from Belgian studies are described in more detail (Keppler *et al* 2010, Gilles *et al* 2012, Gilles *et al* 2013, Degeest *et al* 2014, Gilles *et al* 2014a, Degeest *et al* 2017a, Degeest *et al* 2017b).

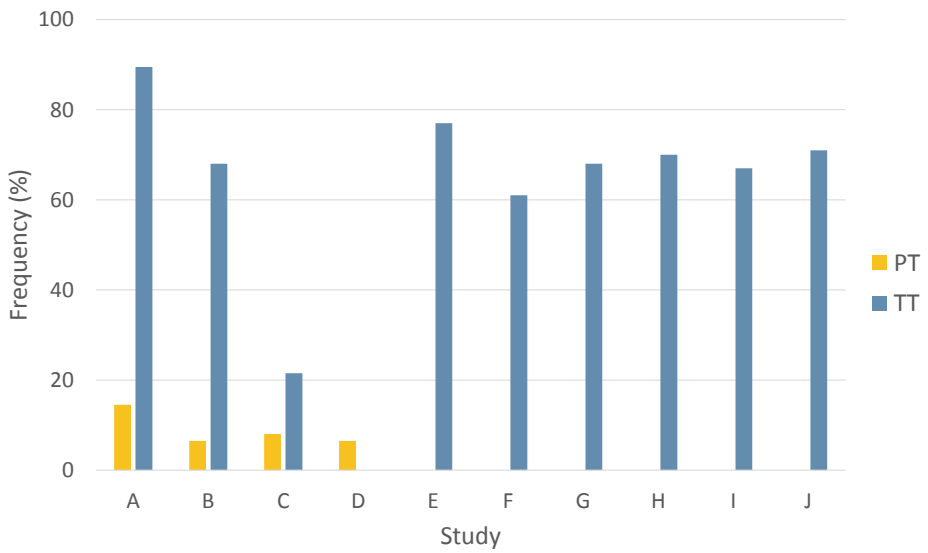

Figure 3 Overview of published data on the prevalence of temporary (TT) and permanent tinnitus (PT) related to leisure-sound exposure. A - (Gilles et al 2012); B - (Degeest et al 2017a); C - (Widen and Erlandsson 2004); D - (Meyer-Bisch 1996); E - (Quintanilla-Dieck et al 2009); F - (Chung et al 2005); G - (Fontana Zocoli et al 2009); H - (Jokitulppo et al 1997); I - (Mercier and Hohmann 2002); J - (Bohlin et al 2011). Adapted from (Gilles et al 2012).

7.2.1 Temporary effects of leisure noise exposure

After being exposed to leisure-sound people report a variety of symptoms with a temporary character. In Table 3 this is illustrated with data obtained from Flemish students between 18 and 30 years old (Keppler *et al* 2015b).

Table 3 Self-reported hearing symptoms after leisure-sound exposure among 163 Flemish young people between 18 and 30 years old (average age 21 years) (per cent). Adapted from (Keppler et al 2015b); figures are rounded.

Symptom	Always	Often	Some-times	Seldom	Never
Tinnitus	6	23	42	15	14
Hearing loss	1	6	33	34	27
Ear pain	0	3	11	28	58
Dullness	0	7	30	28	36

Besides analysing self-reported data, the effects of leisure-sound exposure on the auditory system were also investigated measuring pre-exposure and post-exposure pure-tone audiograms and OAEs (see Footnote 9, p20) indicating cochlear hair cell integrity. After music-related leisure activities—attending concerts, attending discotheques or use of PLDs—or non-musical activities such as a motorcycle rides, most studies found a significant increase in hearing thresholds and reduction of emission amplitudes (Carter *et al* 2014). More specifically, significant changes in hearing thresholds and OAEs were observed in a controlled experiment with 21 young adults after listening to pop-rock music during one hour with a MP3-player (Keppler 2010).

Whether these short term effects are a predictor for long term hearing impairment is uncertain as the relationship between temporary and permanent hearing damage is unknown (Melnick 1991). Short term and long term effects might arise from fundamentally different mechanisms (Nordmann *et al* 2000).

7.2.2 Permanent effects of leisure-sound exposure

Among the permanent hearing r (elated problems caused by leisure-sound exposure, sound-induced tinnitus is the symptom most frequently reported by adolescents and young adults (Widen and Erlandsson 2004, Gilles *et al* 2012, Gilles *et al* 2013). The prevalence of permanent tinnitus related to leisure-sound exposure in the younger population ranges from 3% to 15% (Meyer-Bisch 1996, Widen and Erlandsson 2004, Gilles *et al* 2012, Gilles *et al* 2013, Degeest *et al* 2014, Degeest *et al* 2017b) of which the wide range can be partly attributed to the questionnaire techniques and different definitions of permanent tinnitus (see also 2.1).

Permanent tinnitus appears to affect listening effort, *i.e.* the cognitive requirements necessary to understand speech (Akeroyd 2008, Desjardins and Doherty 2013). This effect was investigated by Ghent University in 2016 (Degeest *et al* 2017b). Listening effort was significantly higher for subjects with sound-induced tinnitus as compared to a control group which might indicate that the capabilities of higher-level cognitive systems are taxed more by the presence of tinnitus.[20]

Sound-induced hearing damage does not always immediately reflect in the pure-tone audiogram of an individual which is currently seen as the golden standard for the evaluation of hearing deficits. When it comes to the detection of hearing damage in an early stage, this technique might not be sufficiently sensitive as, for example, sound-induced tinnitus can be perceived in the absence of any measurable hearing loss (Weisz *et al* 2006, Schaette and McAlpine 2011).

This finding was supported by a Flemish study with an extensive test protocol carried out among 87 young people with a history of leisure-sound exposure (Gilles *et al* 2016). Nineteen students reported permanent tinnitus that they attributed to leisure-sound exposure, and their measures were compared to the non-tinnitus subjects.

[20] This might provide an explanation for the concentration difficulties experienced by chronic tinnitus patients, resulting in a negative impact on quality of life (Tyler 2006).

No significant differences could be found in the peripheral hearing system with pure-tone audiometry, OAEs and auditory brain stem responses between students reporting permanent tinnitus and those that that did not. This implies that no damage could be measured at the level of the outer hair cells in the inner ear which are most sensitive to sound exposure nor that the communication between the inner ear and the lower brain areas was disturbed in the subjects with tinnitus. However, tinnitus subjects showed significant worse speech-in-noise understanding which could not be attributed to peripheral hearing damage.

As such, the suggestion can be made that the decreased speech reception in subjects with tinnitus, in the absence of measurable cochlear lesions, might be due to a more central deficit (Moon *et al* 2015, Gilles *et al* 2016). As a result, it has been proposed that early effects of sound exposure may be affecting the brain more centrally causing central reorganizations and that peripheral hearing damage measured by a tone audiogram is only apparent in a later stage of sound-induced damage.

7.2.3 Data on sound-induced tinnitus in Belgian youth

Until a few years ago the prevalence of hearing symptoms from sound exposure in Belgium as well as abroad, could only be estimated. In 2013, researchers affiliated with Antwerp University performed a cross-sectional survey by means of a self-administered questionnaire (Gilles *et al* 2013). A total of 4800 questionnaires were administered to students of fifteen randomly chosen Flemish high schools (age range: 14 to 18 years). The focus of the questionnaire was on the perception of sound-induced tinnitus as tinnitus is a symptom that can easily be perceived in contrast to a mild hearing loss due to leisure-sound exposure.

An overall prevalence of 75% of temporary sound-exposure related tinnitus was observed. Such a prevalence of temporary tinnitus is consistent with previous studies in other countries. The Flanders study showed, for the first time, an age dependent symptomatology as a significant increase in temporary sound-induced tinnitus with age going from 39% in 14-year-olds to 83% in 18-year-olds was revealed.

The question arises whether this increase is due to the increase in leisure-sound exposure. The frequency of use and volume settings of PLDs did not differ between age groups. Therefore, the observed increase with age may be related to the increased rate of discotheque attendance in the older adolescents. Sound pressure levels in discotheques are typically in the range of 105 dB and more. Previous research learned that leisure-sound exposure with levels above 97 dB may triple the reporting of sound-induced tinnitus (Davis *et al* 1998). Furthermore, frequent PLD users are four times more likely to listen to rather loud music than infrequent users (Ising 1994, Meyer-Bisch 1996, Fligor and Cox 2004, Fligor 2009, Vogel *et al* 2009). In the Flanders study approximately one third of the respondents regularly used PLDs at hazardous sound levels (*i.e.*, more than 80% of the capacity) so an additive effect of years of use of PLDs at excessive sound levels should be taken into account.

When asked about the perception of hearing loss after sound exposure, 39% of the respondents reported to sometimes experiencing a temporary subjective sound-related hearing loss and 11% often to always experiencing a temporary hearing loss. Despite the frequently experienced sound-related symptoms, hearing protection was only used by 5% of the students, as illustrated in Figure 4.

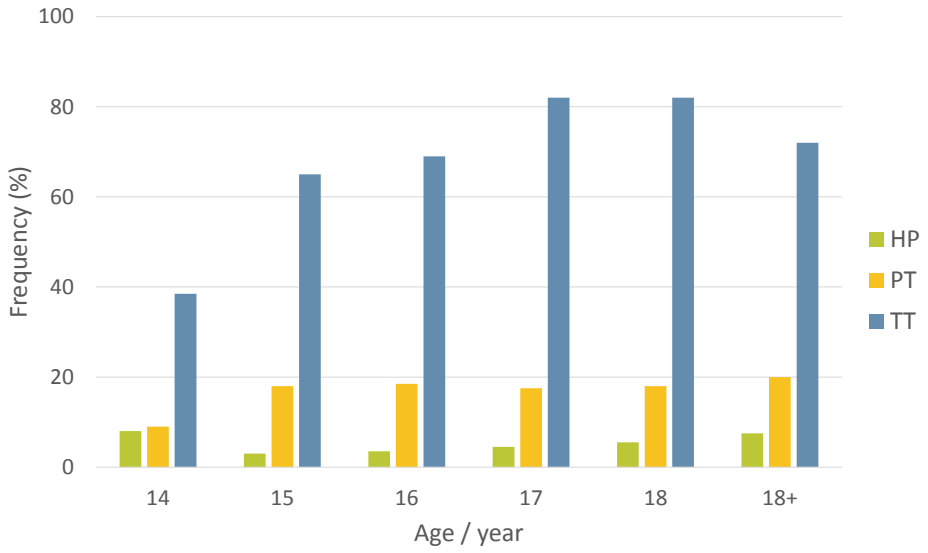

Figure 4 Self-reported tinnitus prevalence and use of hearing protection per age category in the 2013 Flanders study. HP – hearing protection use; PT – permanent tinnitus; TT – temporary or transient tinnitus. Adapted from (Gilles et al 2013).

In the study referred to in Table 2 it was found that temporary tinnitus in at least one ear occurred in 69% of the subjects, while chronic tinnitus in one or both ears is already present in 6% of the subjects (Degeest *et al* 2017b). Tinnitus was mostly perceived bilaterally as a continuous high-pitched pure tone. In men a higher prevalence of chronic sound-induced tinnitus was found which might be attributed to more occupational and leisure-sound exposure in males relative to females (Baigi *et al* 2011). Also, subjects with chronic tinnitus experienced significantly more subjective hearing loss, dullness and difficulties with understanding speech in different listening situations, as compared to subjects with temporary tinnitus or without tinnitus. The presence of chronic tinnitus was significantly associated with self-reported higher lifetime equivalent sound exposures for nightclubs and music venues. Subjects with chronic tinnitus tended to find sound and noise more problematic, and were more aware of their susceptibility to hearing loss, the benefits of preventive action and more willing and convinced to be able to perform a health-orientated behaviour as compared to the subjects with temporary or no tinnitus.[21] Hearing conservation programs targeting youngsters should thus also focus on self-experienced symptoms after leisure-sound exposure.

[21] These data were obtained applying the Youth Attitude to Noise Scale and Beliefs About Hearing Protection and Hearing Loss scale (Svensson *et al* 2004, Widen *et al* 2006, Keppler *et al* 2010),

In addition it was found that hearing thresholds were within the normal range. Age was significantly associated with subclinical hearing loss, defined as normal hearing thresholds but absent OAEs (observed in 7%-9% of the subjects in the study). Nevertheless, there were no significant differences in leisure-sound exposure and attitudes towards sound exposure, hearing loss and hearing protection between subjects with normal hearing and subjects with subclinical hearing loss. However, as age was found to be an important factor, it is possible that the effects of leisure-sound exposure may become more noticeable over time. Therefore, longitudinal research monitoring hearing status over time to evaluate the long-term effects of leisure-sound exposure are recommended, preferably with baseline measures when sound exposure is minimal *e.g*. at preteen years (Carter *et al* 2014).

7.3 Risk awareness

In Chapter 5 information on the soundscape of young people was reviewed. Although there will be a large variety soundscapes among people, also when focussing on music listening only, there are trends with age. These indicate that in the adolescence listening to 'intense' music is popular, but that the popularity diminishes at older ages.

7.3.1 Perceptions

The preceding sections reviewed data that indicate that hearing impairment may occur from listening to loud music, in particular of the 'intense' and 'contemporary' type (Chapter 5), and from attending performances of this music. At present awareness of the hearing risk is found in the medical and public health communities, but much less among the exposed youth themselves both in a qualitative and quantitative sense (Chung *et al* 2005, Quintanilla-Dieck *et al* 2009). Qualitative as the perception of hearing impairment risk scored lower than *e.g.* risks associated with drug and alcohol use, cigarette smoking, sexuality, nutrition and weight loss, depression, acne and sports-related injuries. Quantitative as less than of the order of magnitude of 10 per cent of the surveyed youth considered hearing impairment to be an important health issue as compared to other health risks.

Even though, there is a relationship between music type and loudness. With PLDs the user is largely in control (*cf*. 7.1 and 8.2.1), but in music establishments and at festivals this is not the case apart from using hearing protection. However, in a Belgian study, many respondents changed their opinion about the loudness of the music at a students' party where during the party the sound level increased. At levels of 103 dB(A) about half of the surveyed attendees perceived the music as 'too loud' (Gilles *et al* 2014b). Nevertheless, hearing protection was not used by most of the students. A German study found indications that discotheque visits would not be affected by lowering the sound level (Weichbold and Zorowka 2005).

Adolescents' and young adults' reasons for not using hearing protection are many: it is mainly seen as inconvenient, one forgets to use it and many never even thought about it.

People who did use hearing protection did so mainly to prevent sound-induced hearing damage. But several of the users were also stimulated by earlier experiences of sound-related hearing impairment in the form of tinnitus or hyperacusis (see Footnote 8, p15) and wanted to prevent further damage (Gilles *et al* 2014b).

The limited use of hearing protection of attendees of music events is confirmed in several studies. It has been recommended that the design, appearance, marketing and packaging of hearing protection products should be better targeted at adolescents and young adults (Bockstael *et al* 2015).

7.3.2 Changing perceptions

Mass media campaigns aimed at changing unhealthy lifestyles, have often only a limited success (Gezondheidsraad 2006). In the Dutch report just cited, that was based on an evaluation of several public health campaigns, general recommendations for such campaigns were formulated. They should target the people whose behaviour one wishes to influence, the factors that determine that behaviour and not only the population group as a whole but also the individual in order to enable responding to personal questions. Other recommendations are related to rewards associated with changes in lifestyle and feedback about health improvement. The basic message is that campaigns should be about more than just transmitting information to increase knowledge.

The data on hearing conservation campaigns reflect these findings. In some studies no behavioural changes are observed (Weichbold and Zorowka 2003, Weichbold and Zorowka 2007). However, a Belgian study found more positive effects both with respect to the intention to use hearing protection as well as to the actual use of hearing protection (Gilles and Van de Heyning 2014). In that study over a period of six months the use of hearing protection increased fourfold to about 15 per cent of the people surveyed, whereas the intention to use hearing protection was raised to about 40 per cent. In another Belgian study information about hearing status and about the risks of leisure-sound exposure appeared to be instrumental in lessening overall exposure in a period of six months and in the increased use of hearing protection in about 10 per cent of the study subjects (Keppler *et al* 2015a). However, it was not just the knowledge about hearing status and risks of hearing impairment as such that was related to the results observed.

8 GUIDELINES AND REGULATIONS FOR LEISURE-SOUND EXPOSURE

In medical and policy circles there is a growing awareness that leisure-sound exposure of young people is a cause of concern. This chapter first reviews guidance documents published by international and national public health advisory bodies. Then current regulations in the EU, Switzerland, France and Belgium are summarised.

8.1 International and national guidance

This section reviews guidance documents published by WHO and by public health advisory bodies in the Netherlands and France. The section also includes a summary of the recommendations of a previous SHC-report on personal music players.

8.1.1 World Health Organization (WHO)

Environmental Health Criteria

In 1980 the WHO published an extensive report on 'Noise' in its Environmental Health Criteria series (WHO 1980). In accordance with its title, the document focuses on 'unwanted' sound (*cf*. 1.3 and Annex I); recreational sound exposure is not addressed. With respect to the health effects of noise, apart from noise-induced hearing loss, *inter alia* annoyance, stress and sleep disturbance are mentioned. The latter type of effects arise from environmental noise exposure both outdoors and indoors at levels at and above of L_{Aeq} of 35-55 dB(A).

Noise-induced hearing loss is considered to be an effect primary of long time exposure to noise at work. The document states that at $L_{EX,8h}$-values below 75 dB(A) there is "no identifiable risk of hearing damage" even for long term exposure (8 hours per day, 40 hours per week, 50 weeks per year for several tens of years up to a working lifetime). For higher levels "there is an increasing predictable risk" for hearing damage.

Guidelines for Community Noise

In 1995 the WHO published a document on 'Community Noise' (WHO 1995) with a revised version appearing in 1999 (WHO 1999). The document is at present being updated in the form of WHO Environmental Noise Guidelines for the European Region.[22] This document reiterates that "hearing impairment is not expected to occur at $L_{EX,8h}$ levels of 75 dB(A) or below, even for prolonged occupational exposure".[23] The community noise guidelines also address hearing loss from leisure-sound which is considered to be absent at $L_{Aeq,24h}$ levels of 70 dB(A) or below.[24] The document further addresses impulse noise which in the work place should not exceed 140 dB (L_{peak}). However for children playing with noisy toys L_{peak} should never exceed 120 dB.

Similar to the earlier Environmental Health Criteria document the community noise guidelines address other effects from environmental noise sources. But now exposure to recreational music is also mentioned. The guidelines suggest to control exposure to loud music at ceremonies, festivals and entertainment events by applying occupational noise exposure standards. The document states that exposure of attendees should be below $L_{Aeq,4h}$=100 dB(A) for at most four times a year.

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22 http://www.euro.who.int/en/health-topics/environment-and-health/noise/activities/development-of-who-environmental-noise-guidelines-for-the-european-region, accessed 12-05-2017

23 The document writes the exposure measure as $L_{Aeq,8h}$; *cf.* Annex I

24 $L_{Aeq,24h}$=70 dB(A) approximately corresponds to $L_{Aeq,8h}$=75 dB(A), assuming that outside the 8 hours period the exposure is considerably below 75 dB(A).

The maximum sound level L_{Amax} should always be below 110 dB(A). For PLDs the community noise guidelines refer again to the exposure limit of $L_{Aeq,24h}$ of 70 dB(A) which translates into a daily one-hour exposure limit ($L_{Aeq,1h}$) of 85 dB(A).

Recreational exposure to loud sounds

More recently the WHO published a document on hearing loss due to recreational sound exposure (WHO 2015). This publication reviews studies on such exposure and focuses on teenagers and young adults. The authors estimate that more than a "[…] billion young people worldwide could be at risk of hearing loss due to unsafe listening practices", but do not provide data to support this estimate. They review the literature on temporary and permanent hearing threshold shifts and on sound-induced temporary and chronic tinnitus. Cognitive overload and traffic accidents from excessive or inappropriate use of PLDs are also mentioned.

According to the document the highest "safe exposure" is considered to be 85 dB(A) ($L_{Aeq,8h}$). The value is clearly obtained from occupational noise regulations that often specify a reference value of $L_{EX,8h}$=85 dB(A). The SHC considers the term 'safe' somewhat misleading and at odds with the other WHO documents reviewed above. As is clearly stated in the references referred to in the document the value of 85 dB(A) is "a 'trade-off' between practicability and protection" (Thorne 2008) and not a level at which in healthy individuals no hearing damage will occur.

To prevent sound-induced hearing loss (and other symptoms of hearing damage) from recreational sound exposure the document lists elements of prevention strategies. Without further discussion these strategies are based upon the 85 dB(A) value mentioned just above. Elements described are:

- Keeping the volume down, *i.e.* below 85 dB(A).
- Using carefully fitted earbuds
- Using noise-cancelling earphones or headphones, which can reduce the need to raise the volume of the listening device
- Monitoring sound exposure; the authors refer to smartphone apps that enable individuals to obtain an indication of sound levels
- Limiting the time engaged in noisy activities; the authors suggest breaks at concerts and similar events and limiting PLD use to one hour per day
- Moving away from loud sounds
- Wearing earplugs
- Respecting safe listening levels; apart from referring again to the 85 dB(A) value the authors also urge people to be alert on warning signs of hearing loss, such as tinnitus and difficulty in understanding speech and following conversation in noisy environments
- Regular hearing check-ups.

The overriding recommendation is "be aware". This holds for warning signs of hearing impairment, but also for the safety aspects of PLDs and measures taken at music events.

8.1.2 Health Council of the Netherlands (GR)

In 1994 the Health Council of the Netherlands (GR) prepared an advisory report on noise and health and on the impact of noise exposure on the Dutch population (Health Council of the Netherlands: Committee on Noise & Health 1994). It was prepared by an international committee of experts and based on literature reviews commissioned by the GR to the TNO organization (Passchier-Vermeer 1989, 1993). The report reviews the scientific evidence for a great variety of reported health effects from sound exposure, discusses the levels at which in epidemiological studies health effects were observed (so-called observation thresholds) and presents in so far data allowed estimates of the impact on the Dutch population.

For noise-induced hearing loss the report lists observational thresholds of 75 dB(A) ($L_{EX,8h}$) for occupational exposure and 70 dB(A) ($L_{Aeq,24h}$) for environmental exposure. Hearing loss risk for the unborn child due to occupational exposure of pregnant women is also mentioned. Due to a scarcity of data the report specifies the observation threshold as below 85 dB(A) ($L_{EX,8h}$). The GR did not review data on tinnitus, although the background documents mention tinnitus in relation to effects in young people (Passchier-Vermeer 1989) and to exposure to noise of low-flying jet airplanes (Passchier-Vermeer 1993).

The report estimates the fraction of the population of the Netherlands that was affected by the effects discussed. Estimates are presented in terms of orders of magnitude given the uncertainty and often scarcity of the available data and their applicability—in case of data from elsewhere—for the Dutch population (in 1994 somewhat more than 15 million). Occupational noise-induced hearing loss would affect 100 000 to 1 000 000 people. A similar estimate is given for the effects of pop music on hearing, both with respect to visiting concerts and to listening with head phones. The population group that might have hearing threshold shifts of more than 15 dB is estimated an order of magnitude lower, *i.e.* between 10 000 and 100 000. The GR could not derive estimates for the impact of noisy children's toys.

8.1.3 Haut Conseil de la santé publique (HCSP)

In 2013 the French *Haut Conseil de la santé publique* (HCSP) addressed the effects of exposure to amplified music and formulated acceptable levels for such exposures (Haut Conseil de la santé publique 2013). In particular the HCSP was asked to propose quantities to be used for protection of the public against the effects of amplified music, to propose values for these quantities that would guarantee an acceptable risk for the exposed public, and finally if deemed necessary, to propose specific values for children. At the time of the request for advice exposure to amplified music was already regulated in France (*cf.* 8.2.3). The report does not address exposure to music from PLDs.

Based on a review of the scientific literature the HCSP-report concludes that any danger of excessive levels of amplified music only depends on the sound level and exposure duration and not on the cultural appreciation of the music.[25]

[25] The HCSP-report mentions but did not review physiological and psychological effects of music exposure; only the effects on hearing are considered.

So sound level and exposure time are the relevant quantities for risk evaluation. The HCSP bases its recommendations for acceptable levels on an equivalent sound level of 85 dB(A) over 8 hours ($L_{Aeq,8h}$), which it denotes as a "danger threshold" [26]. In addition the report proposes to limit the peak sound level and apply both the A-weighting and the C-weighting (cf. Annex I). The exposure limits defined in the current French regulations (*cf.* 8.2.3), $L_{Aeq,10\text{-}15min}$=105 d(A) and L_{peak}=120 dB, are deemed to be insufficiently protective. The HCSP could not find data that indicated a particular vulnerability of children with the exception of prematurely born children with an insufficiently developed hearing organ. However, some data indicated that exposure at young ages might lead to an increased vulnerability later in life and for that reason special attention to sound exposure in establishments for the young is considered to be in order.

On the basis of these considerations the HCSP recommends the curve marked '85' in Figure 6, Annex I as separating a domain of acceptable sound levels and listening times (15 minutes to 8 hours) from a domain where hearing was considered to be 'at risk'. Corresponding to this recommendation exposure limits are proposed of $L_{Aeq,15min}$=100 dB(A) and of L_{Cpeak}=120 dB(C). For a young public (less than 18 years old) these standards should be strictly adhered to.

The HCSP notes than at events for an adult public the sound levels might exceed the standards proposed. For those events it recommends that the equivalent sound level measured over every last 10 minutes should be displayed and that the display should also inform the public about the risk values according to the curve '85' in Figure 6, Annex I (e.g. 91dB/2hours, etc.) with the advice to take a 'sound break' when the exposure is in the domain 'at risk'. For that purpose a recuperation zone should be present with a sound level below 85 dB(A). Women in the final three months of pregnancy should be warned about danger for their unborn child. Furthermore hearing protection should be available without charge.

Finally the HCSP recommends that sound levels for any event are to be registered and kept for at least two years. It concludes with stressing the need for information campaigns to make its proposals understood and accepted.

8.1.4 Superior Health Council

As referred to in the request for advice, the SHC published a report on 'digital music players (MP3)' in 2007. In this report the SHC deems digital music players to be more dangerous for hearing than its analogue predecessors, also because of changing ways of use that permitted longer exposure duration to high levels. At that time pertinent data on the hearing of youth in Belgium were lacking, but the report concludes on the basis of the international scientific literature that hearing impairment related to excessive leisure-music exposures is to be expected. It recommends to carry out epidemiological studies in Belgium, not only using tone audiometry, but also techniques based on OAEs.

The SHC recommends a sound pressure level limit of 80 dB(A) for extended listening times and a never to exceed a value of 90 dB(A), even not in case of short listening times.[27]

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[26] In French: "seuil de dangerosité".

[27] The report did not specify the integration time, but mentioned that hearing impairment might occur after a daily exposure to $L_{Aeq,1h}$=90 dB(A).

For that reason it is recommended that music players are to be constrained to emit sound levels of maximally 90 dB(A) preferably taking into account the type of head phones or ear buds offered. Also information on safe listening practices should be part of the device's instruction manual. The SHC recommends that the device shows a decibel-scale or in any case an indication of the volume setting corresponding to 80 dB(A).

The report draws attention to the trend of marketing music players for young children, without making specific recommendations. It also refers to the Belgian regulation of an equivalent sound level of 90 dB(A) for establishments and events with amplified music (*cf.* 8.2.4) and urges strict adherence to this exposure limit. Finally the SHC stresses the importance of information campaigns to raise awareness among youth and their parents of the risks of inappropriate use of PLDs.

8.1.5 Synthesis

The guidance reviewed has in common that for recreational sound exposure, be it using PLDs or attending amplified music performances, it is based on data on noise-induced hearing loss at work. However, the WHO reports of 1980, 1995 and 1999 and the GR report derive guidelines for exposures from what might be called a 'health-based recommended exposure limit'[28] of $L_{Aeq,8h}$=75 dB(A) for which at daily occupational exposure for many years up to a working-lifetime no exposure-related hearing impairment was observed. Using the equal energy principle (*cf.* Annex I) limits for other exposure durations are derived. The 2015 WHO report and the HCSP report base their recommended exposure limits on regulatory standards, in particular on the $L_{Aeq,8h}$=85 dB(A). This value is not purely health based but derived from a 'trade-of' between practicability and protection considerations (Thorne 2008), even though exposures below the limit are denoted as 'safe' by the WHO or not 'at risk' by the HCSP. The 2007 SHC-report takes an intermediate position by referring implicitly to $L_{Aeq,8h}$ of 80 dB(A).

The SHC-report provided the most detailed recommendations for PLDs. These are stricter than the later enacted European standards (*cf*. 8.2.1).

In so far the reports propose elements for regulations, they all stress the necessity of information campaigns. The 2015 WHO report and the HCSP report list additional elements that the SHC deems worth considering.

8.2 International and national regulations

In the 20th century the number of industrial and environmental sound sources increased. Exposure to sound became more and more ubiquitous. Relevant sources were (and are) industrial operations, motorized traffic and consumer products. With the growing awareness that sound exposure is a risk factor for hearing damage, national and international organizations issued guidelines to reduce exposure and hearing damage (*cf*. 8.1).

[28] A health-based recommended exposure limit specifies the level of exposure at or below which the chance of any adverse health effect may reasonably be expected to be nil (Health Council of the Netherlands: Committee on Health-based recommended exposure limits 1996).

Authorities enacted legislation and implemented regulations with the ultimate objective to foster health by preventing or limiting hearing damage. This section presents a short overview of current legislation and regulations in Belgium and elsewhere.

8.2.1 EU

Occupational exposure

Noise policy development in the European Union (EU) focused originally on occupational noise exposure at work with the aim to reduce noise-induced hearing loss. A first directive was issued in 1986 to be implemented by the Member States in 1990 (EU 1986). Exposure levels were specified above which workers had to be informed about the risk to hearing and above which hearing protection should be used.

In 2003 a new directive was published to be implemented at the latest in February 2006 (EU 2003). It was stricter than its predecessor and specified an exposure limit and action levels related to health risk information and the availability and use of hearing protection. The values stated in the directive are relevant for the present report as they are often used as reference levels in the assessment of the risk on non-occupational sound exposure.

The exposure limits are 87 dB(A) for the equivalent sound level over a working day ($L_{EX,8h}$, *cf*. Annex I) and 200 Pa (or L_{Cpeak} = 140 dB(C)) for the instantaneous C-weighted sound pressure (p_{peak}, *cf*. Annex I). They relate to the exposure in the ear, *i.e.* taking into account the attenuation by hearing protection. Keeping exposures below these limits does not imply that no damage may occur. In order to reduce the risk of hearing damage, above the upper action level ($L_{EX,8h}$ = 85 dB(A), p_{peak} = 140 Pa or L_{Cpeak} = 137 dB(C)) hearing protection should be used and above the lower action level ($L_{EX,8h}$ = 80 dB(A), p_{peak} = 112 Pa or L_{Cpeak} = 135 dB(C)), hearing protection should be available. In case of very variable day to day exposures equivalent sound levels may be averaged over a 5-day working week ($\overline{L}_{EX,8h}$).

Environmental exposure

In the last decade of the 20th century environmental sound exposures from road, rail and air traffic and from industrial operations became a policy issue. The focus was not so much on hearing damage, but on annoyance and sleep disturbance and related to these phenomena on cardiovascular effects. The so-called *Environmental Noise Directive* was published in 2002 to be implemented by the Member States in September 2006 at the latest (EU 2002).

The directive does neither prescribe action levels, nor exposure limits. It obliges EU Member States to produce strategic noise maps for urban agglomerations and near busy road, railways and airports. The quantities to be used in noise mapping are the day-evening-night level and the night-time noise indicator (*cf*. the directive for definitions of these A-weighted equivalent sound levels).

Consumer product exposure

With respect to equipment for outdoor use a 2009 EU-directive sets limits on noise emissions (EU 2009)). This directive is related to the so-called Machinery Directive setting standards for equipment on the European market. Emission levels for music producing equipment are not covered by this legislation.

Personal listening devices

For the present report the legislation setting standards for PLDs is of relevance (European Commission 2009). Adherence to standards prepared by bodies such as CENELEC[29] in order to label a product with a CE-marking is required. The European Commission prescribed safety requirements for 'personal music players' to be incorporated in new or revised standards for audio, video and similar electronic apparatus and for information technology equipment. The safety requirements were specified in terms of maximum equivalent sound levels of 80 dB(A) for 40 hours per week listening and 89 dB(A) for 5 hours per week listening in order to avoid hearing damage. Furthermore devices should contain warnings and information about listening behaviour and risk to hearing. CENELEC established two standards in 2011 (EN 60065:2002/A12:2011 and EN 60950-1:2006/A12:2011) and the European Commission accepted these standards as fulfilling the safety requirements published earlier (European Commission 2012).[30]

The standards require that digital PLDs shall have a sound level limit of 85 dB(A) (SGS 2011). However, an override function is permitted which allows the user to increase the output to a sound level up to 100 dB(A). If the user does so, a warning message should be generated every 20 hours.[31] This standard applies to equipment put on the market from February 2013 onwards (Hear-It 2013). Analogue players lacking any kind of digital sound signal processing were exempted from the standard until the end of 2015 (SGS 2011).

Toys

Sound emission from toys is covered in a way similarly to that from PLDs. In 2009 the EU published a directive "on the safety of toys" that came into force in the EU Member states in 2011. Annex II of this directive states that sounds emitted by toys should not be able to impair children's hearing.[32] To acquire a CE-label indicating conformity with this requirement, European Standard EN71-1 (NBN 2015) applies. The standard in its present form (it was amended in 2013) specifies A- and C-weighted sound emission levels depending on the assumed use distance and the exposure category (MTS 2013).

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29 CENELEC – European Committee for Electrotechnical Standardization

30 These standards are expected to be replaced by EN 62368-1 in the coming years (UL 2012, European Commission 2015).

31 For equipment designed to be used by young children a maximum of 80 dB(A) is applicable.

32 Annex II, article I.10 reads: Toys which are designed to emit a sound shall be designed and manufactured in such a way in terms of the maximum values for impulse noise and continuous noise that the sound from them is not able to impair children's hearing.

Category 1 applies to sound emissions longer than 30 seconds and category 3 to sound emissions shorter than 5 seconds; category 2 is the intermediate category. *E.g*. handheld toys with a assumed use distance of 25 cm have sound level limits at 50 cm of 80, 85 and 90 dB(A) for category 1, 2 and 3 respectively with $L_{Cmax,peak}$ = 110 dB(C). For toys with headphones or earphones the limit is 85 dB(A) to be measured in a simulator (category 1 only) and converted to a free field equivalent.

Recreational sound exposure

Regulations for recreational sound exposure, such as exposure at music festivals or in discotheques are not covered by EU legislation, have to be developed nationally or regionally, and implemented at a national or local level.

8.2.2 Switzerland

In 2007, amended in 2012, the Swiss Federal Council issued a decree aimed at protection against damage from sound exposure and laser radiation at public events (Conseil fédéral suisse 2007). The decree classifies events on the basis of the equivalent sound level over 1 hour ($L_{Aeq,1h}$, *cf*. Annex I) and the maximum sound pressure level measured in the 'Fast' mode ($L_{Amax,F}$, *cf*. Annex I). No requirements are laid down in the decree for events where $L_{Aeq,1h}$ does not exceed 93 dB(A) and $L_{Amax,F}$ does not exceed 125 dB(A) during the full duration of the event. Events mainly meant for children below the age of 16 should always adhere to these limits.

In case $L_{Aeq,1h}$ exceeds 93 dB(A) but remains below 96 dB(A) throughout the duration of the event, specified requirements apply. The public should be warned that sound levels may attain 96 dB(A) and should be informed about the hearing risks. Furthermore, sound levels have to be registered and hearing protectors have to be provided without charge.

The third category refers to events of a maximum duration of 3 hours where $L_{Aeq,1h}$ exceeds 96 dB(A). The requirements are similar to the preceding category (warning, information, hearing protection, registration). In addition $L_{Aeq,1h}$ may not exceed 100 dB(A) and a so-called recuperation zone with a maximum $L_{Aeq,1h}$ of 85 dB(A) has to be freely accessible to the public throughout the duration of the event.

Events with higher levels are not allowed. The requirement of a maximum sound pressure level $L_{Amax,F}$ of 125 dB(A) applies in all cases.

8.2.3 France

In France regulations apply for locations with amplified music (Legifrance 1998, Bruit.fr 2013). The regulations are part of the 'environmental code', but also refer to the attendees. In principle all locations are covered where regularly amplified music is played, including for example sports clubs and pubs.

The regulations specify an A-weighted maximum equivalent sound level of 105 dB(A) measured over 10 to 15 minutes (France 1998) and a maximum peak sound pressure level (L_{peak}) of 120 dB.

Locations where playing amplified music is not the primary objective the regulations apply in case the A-weighted sound level exceeds 85 dB(A). The term 'regularly' is interpreted as 12 times per year or 3 times in 30 days in case music is played during a part of the year.

The *Haut Conseil de la Santé Publique* has proposed new standards for music exposure (8.1.3) (Haut Conseil de la santé publique 2013).

8.2.4 Belgium

Federal

The Royal Decree of February 24, 1977 specifies sound standards for public and private establishments (KB 1977). The decree is no longer applicable in Flanders (Vlaamse Regering 2014) and is slightly modified for the Walloon Region. It will be replaced in the Brussels Capital Region (Brussel-Bruxelles 2017a). The regulations apply both for the exposure of attendees as well as the exposure of neighbours. All type of locations are subject to the regulations, including outdoor festivals.

The decree specifies a maximum sound pressure level of 90 dB(A) ($L_{AMax,S}$; *cf*. Annex I) which only applies in public establishments and at locations where people may be exposed.

The SHC has no information to which extent the decree is adhered to. However, some data indicate that this is not always the case (Van Ranst 2012). See also (Brussel-Bruxelles 2017b).

Flanders

The Flemish government amended the Royal Decree of 1977 in 2012 and repealed it in 2014 for the Flemish region (Vlaamse Regering 2012, 2014). The regulations in force at present are part of the Decree concerning Environmental Licences *VLAREM*[33] and refer to all public establishments and events with amplified music (Vlaamse Overheid 2012). The regulations distinguish three categories. In case $L_{Aeq,15\text{min}}$ is less than 85 dB(A), no requirements with respect to sound exposure are specified. When the A-weighted equivalent sound level over 15 minutes regularly, *i.e.* more than 12 times per year, exceeds 85 dB(A) but not 95 dB(A), the second category, a so-called class 3 license is required. For regular events with $L_{Aeq,15\text{min}}$ larger than 85 dB(A) but not exceeding $L_{Aeq,1\text{h}}$=100 dB(A), the third category, a class 2 license is required. For occasional events in the latter two categories a specific license from the local government should be obtained.

For events in the second category the equivalent sound level should be measured and be visible for the person who regulates the sound volume. The same applies for events in the third category be it that the measured sound levels should be registered for later inspection by the authorities. At the latter events hearing protection ('ear buds') should be available for the public free of charge.

[33] https://www.lne.be/milieuvergunningendecreet-vlarem-i-ii-en-iii, accessed 12-05-2017

Licenses are to be obtained from the municipal government and may be more restrictive than *VLAREM* requires, especially in case of occasional events. The decree also specifies environmental sound levels to prevent or reduce nuisance in the surroundings of the establishment or event.

Brussels

In January 2017 the Government of the Brussels Capital Region enacted legislation to regulate amplified music exposure and to replace the Royal Decree of 1977 (see above) (Brussel-Bruxelles 2017b, a). The Brussels Government explains that the 1977 federal regulation is outdated given the changes in music exposures (higher levels, more low frequency sound). It also refers to the Flemish legislation and to the lack of inspections.

The regulations resemble those of Flanders but with relevant differences. They specify a three-category structure. As long as $L_{Aeq,15min}$[34] remains below 85 dB(A) no specific requirements apply. In case the exposure exceeds this level but remains below $L_{Aeq,15min}$ = 95 dB(A) and $L_{Ceq,15min}$ = 110 dB(C) the decree requires information of the attendees about the sound levels (display) and about the risk of temporary and permanent hearing impairment. The decree allows performances with higher levels, be it with maxima of $L_{Aeq,60min}$ = 100 dB(A) and $L_{Ceq,60min}$ = 115 dB(C). In that case the requirements of the preceding category apply. In addition, hearing protection should be provided free of charge or at cost and a quiet zone with $L_{Aeq,15min}$ below 85 dB(A) should be available for the attendees. Also a reference person should be nominated and responsible for compliance with the regulations.

8.2.5 Synthesis

International and national sound regulations currently cover four areas:

- The prevention of hearing loss from occupational noise exposure
- The prevention of annoyance and sleep disturbance from environmental noise exposure, mainly related to road, rail and air traffic and to industrial noise exposure
- The prevention of annoyance from noise emissions from outdoor uses of equipment
- The prevention of hearing loss and other hearing damage from leisure-sound exposure, mainly related to PLDs and music exposures in publicly accessible locations.

In Europe the first three areas are fully or partly (in the case of environmental noise) regulated on the EU level. The last category, which is the most relevant for the present report, is not regulated on a European level apart from the requirements for PLDs.

The SHC notes that with respect to PLDs the regulations will only gradually lead to an improvement. Even though personal electronic equipment is often used for much shorter periods (a few years) than its technological life time, it will take several years before all equipment in use conforms to the standard. This underlines the necessity of information and education on the use of these devices as a way to prevent or in any case minimize any hearing damage.

[34] The decree adds the term “glijdend” (in Dutch) or “glissant” (in French) to the equivalent sound level over 15 minutes, explaining that the level applies at any time (second) during the amplified music exposure.

With respect to health effects due to exposure to amplified music in establishments and at concerts and festivals the SHC notes that regulations in Belgium are not consistent. In the Brussels Capital Region and in the Walloon Region the 1977 regulations still apply, but whether they are observed in actual practice is doubtful (Van Ranst 2012, Brussel-Bruxelles 2017b). In the Flemish Region a more comprehensive legislation is in force since the beginning of 2013, whereas in the Brussels Region new regulations are expected to become into force in 2018. The SHC emphasizes that consistent and comprehensive regulation for the whole of Belgium should be considered to be a public health target.

A few data are available on the compliance with the Flemish regulations (Keymeulen and Van de Wiele 2014, Quisquater and Vandekerckhove 2015). Although it is difficult to generalize the results of these studies it appears that a considerable fraction of establishment owners and event organizers are aware of the regulations, which however implies that another considerable fraction had no or insufficient knowledge of the regulations and their background. This may partly explain why in some cases prescribed exposure limits were exceeded and sanctions had to be effected. These findings again underline the necessity for information and education. Efforts should not only focus on the attendees, but also on the owners and organizers. The SHC considers the information booklet of the Flemish authorities (Vlaamse Overheid 2012) to be a good instruments as part of such efforts.

9 PREVENTION OF HEARING IMPAIRMENT FROM RECREATIONAL SOUND EXPOSURE

9.1 Is there reason for concern?

The short answer of the SHC to this question is: yes! Even though systematic data on sound exposures are lacking, the soundscape of children, adolescents and young adults in affluent societies like Belgium is such that concern is justified. For young children (say up to the age of 12 years) noisy toys, including computer games, as well as attending a kindergarten or an after school centre, are increasingly relevant sources of sound exposure. For adolescents and young adults amplified music from PLDs, and in discotheques, bars, concerts and festivals is a dominant source. This apart from sources as noisy equipment and motorcycles. The sound levels are such that short term effects will be observed and depending on the frequency and duration of the exposure permanent sound-related hearing impairment is to be expected or at least plausible.

9.2 What are the effects of present day soundscapes

With respect to the leisure-sound exposure of young children solid data on short or long term effects are lacking. However, given the information on exposure levels and the fact that weekly exposure times may be considerable, the SHC considers a long term effect on hearing possible.

Short term effects from exposure to amplified music are well documented for adolescents and young adults. Tinnitus is commonly reported after loud-music exposure as well as dullness and decreased hearing. These effects appear to be reversible, but the SHC underlines that research with advanced methods has found indications that subclinical damage of the hearing organ occurs. This damage might impair the hearing later in life.

To which extent non-reversible effects occur is not certain. However, as reviewed above a non-negligible fraction of young people report permanent tinnitus related to leisure-sound exposure. Assuming that models for occupational noise-induced hearing loss also apply to leisure-sound exposure, hearing loss due to amplified music is to be expected. However, epidemiological confirmation is difficult to obtain, in particular due to uncertainties in exposure frequency and duration.

Notwithstanding the uncertainties, the SHC expects that leisure-sound exposure may negatively affect hearing and thus has a negative impact on the quality of life later in life. An extra argument for taking a precautionary stance and promote preventive measures is the fact that hearing damage is irreversible and cannot be cured given present day medical knowledge. At best it can be (partly) compensated.

9.3 Recommendations for prevention

As hearing impairment cannot be cured, all efforts should be directed at preventing damage from sound exposure. Ideally exposures should remain below health based exposure limits (8.1.5). In the real world this is hardly feasible. In occupational settings there is trade-off between economic and public health interests. Also with leisure-sound exposure trade-offs abound. Public health objectives may conflict with personal preferences and societal trends, as well as with commercial interests.

The SHC distinguishes three approaches in preventing loud sound exposures:

- Creating awareness though information and education
- Limiting source emissions
- Regulating amplified music.

Creating awareness

Above the Council already emphasised the importance of public information and education about the effects of excessive sound exposure on hearing and ways to prevent such effects. Given the increasing sound exposure of children and adolescents such efforts should also be part of the primary and secondary school curriculum. Public campaigns initiated by authorities and public health organisations should relate to attitudes towards and preferences for present day soundscapes (Chapter 5 and 7.3). An example is the 'health day' during the Brussels 'week of the sound' that in January 2017 celebrated its 7th edition.[35] Websites initiated by public health organisations, such as the Dutch National Hearing Foundation[36], the Flemish Government[37] or the international Hear-it[38] organisation may be instrumental in information efforts. Such sites often enable a hearing check. Also forum-sites by youth themselves are a means for creating awareness.[39] Venues with music performances are another opportunity for information on the effects of sound exposure and on the advantages and use of hearing protection. Licences for such performances often require this type of information (8.2).

In 7.3.2 some general recommendation for public health campaigns on leisure-sound exposure and hearing impairment were listed, which the SHC supports. The Council emphasises that campaigns should not only focus on the long term hearing impairment but take into account the short term symptoms such as hearing loss, tinnitus and hyperacusis[40]—also when they appear to be temporarily. These symptoms are often seen as a 'normal' condition after leisure-sound exposure, but should be pictured in information and education efforts as warning signals for possible permanent hearing impairment.

The adolescence period is of prime importance for preventive efforts. Is the use of PLDs among children still limited in frequency and duration, at the age of around 12-13 years such devices are used to a greater extent and at higher output levels. Advice on the correct use of PLDs, *e.g*. whether to listen with headphones or inserts, and information on the health risk of high output levels for longer periods is indispensable. The SHC supports the use of PLDs with warning systems as prescribed at present by European standards.

At the age of 16-18 years, when adolescents start to attend music venues such as festivals, concerts, discotheques, *etc.*, the recommendations mentioned above (see also 7.3.2) apply even more. As already mentioned school programmes are a suitable instrument for discussing hearing health and ways to achieve and maintain good hearing also later in life. The SHC underlines that preventive efforts are not a one-time exercise but should part of a permanent programme of health impairment prevention. Only then are information and education campaigns effective.

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35 French: La semaine du son - http://lasemaineduson.be/, accessed 12-05-2017; Dutch: Week van de klank - http://deweekvandeklank.be/, accessed 12-05-2017.

36 Nationale Hoorstichting (Netherlands): http://www.hoorstichting.nl/, accessed 12-05-2017.

37 Vlaams Agentschap Zorg en Gezondheid, http://www.ietsminderisdemax.be/, accessed 12-05-2017.

38 Hear-it (International): http://www.hear-it.org/, accessed 12-05-2017.

39 For example 'Help ze niet naar de tuut', http://tuut.lne.be/, accessed 12-05-2017).

40 See Footnote 8, p26

Limiting source emissions

In European product regulations the objective of preventing hearing impairment is reached by limiting sound emissions through industry standards (8.2.1). Although within the framework of our economic system the SHC can support this approach, a few comments are in order. The first comment is that standards do not guarantee prevention of hearing impairment. As has been discussed above they are usually based on occupational standards that are already a trade-off and mainly directed at hearing loss. Even when accepting the use of occupational findings for leisure-sound exposure evaluation one may question whether the standards are also sufficiently protective for other effects than hearing loss such as tinnitus. Secondly the notion of conformity with the standards depends on prototype testing; in practice products on the market may fail the requirements of then standard (see *e.g.* (McLaren *et al* 2014)). Thirdly the preventive effect of a standardised product also depends on the appropriate use by the consumer. Finally the global Internet-based trade enables users to acquire products that are not in conformity with the national and European standards.

In the view of these considerations the SHC recommends that federal and regional authorities are vigilant and regularly evaluate the efficacy of the standards and involve industry and consumer organisations in these evaluations. Even though the effects of sound exposures of young children are uncertain, the SHC recommends a precautionary approach, which implies that emission standards for products to be used for young children should be stricter than for products used by adolescents and adults.

Regulating events

Whereas in its 2007 report the SHC recommended strict adherence to the 1977 Royal Decree on exposure to amplified music in public locations and at concerts and festivals, the Council now considers this regulation obsolete and not effective given the changes in soundscape in the last decades. It notes that in Flanders new regulations for amplified music events already apply and that in Brussels new regulations will come into force in the beginning of 2018. In the Walloon Region the 1977 regulation still applies. The SHC recommends that also in Wallonia regulations similar to those in the two other regions of the country are enacted in order to better protect attendees of music events against hearing impairment from sound exposure.

Even though the new regulations are an improvement over the older ones, they are not fully protective and are to be considered as a compromise between public health considerations, music industry interests and (presumed) preferences of attendees. Here again the recommendation of a vigilant administration applies as well as of regular evaluations of the efficacy of the regulations. The SHC also defends more uniformity and harmonisation of exposure limits and other requirements throughout the whole country. Such harmonisation is a loadable goal where the most protective regulation should be considered as a point of departure and not the least protective ones.

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ANNEXES

Annex I TERMS RELATED TO SOUND

This annex is mainly based upon an international standard (International Organization for Standardization 1990) and reports of the Health Council of the Netherlands (GR) (Health Council of the Netherlands: Committee on Noise & Health 1994) and the World Health Organization (WHO) (WHO 1999).

Sound and noise

Sound is a phenomenon with alternating compressions and expansions of air which propagate from a source in all directions. These compressions and expansions represent pressure variations around the atmospheric pressure. The number of pressure variations per second is the frequency of a sound and is expressed in Hz[41]. A pure tone is characterized by a single frequency. The frequency determines the pitch of a sound: a high pitched tone (*e.g.* 4000 Hz) has a squeaking sound, a low pitched tone (*e.g.* 200 Hz) a humming sound.

Physically, there is no distinction between sound and noise. Sound is a sensory perception and the complex pattern of sound waves with a variety of frequencies is labelled noise, music, speech *etc*. Noise can be considered to be unwanted sound.

Sound pressure level

The level (L) of a sound is related to the sound pressure (p). In practice, sound pressures range from less than 20 μPa[42] up to more than 200 Pa, a range of 1 to 10 million. Therefore, in acoustics, the logarithm of the sound pressure relative to a reference sound pressure (p_o) is usually taken as a basis for the sound measure. A reference sound pressure of 20 μPa is generally used. It represents the level of a tone just audible at 1000 Hz for someone with normal hearing. The sound pressure level is expressed in decibel (dB) and can be calculated from:

$L = 10 \times \log \frac{p^2}{{p_0}^2}$ dB (p_0=20 μPa)

Frequency weighting

The human hearing organ is not equally sensitive to sounds with different frequencies. Therefore, to obtain a sound level measure to approximate the perceived intensity sound pressure levels are rated at the different frequencies in about the same way as the human hearing organ does. The most common method for this rating is applying the so-called A-filter, which is plotted in Figure 5 as a function of frequency. When the sound pressure levels of a sound are measured using the A-filter, the result is given as the sound level in dB(A).

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41 Hz – hertz, SI unit of frequency; 1 Hz = 1 s^{-1}

42 Pa – pascal, SI unit of pressure; μPa – micropascal, 0.000 001 Pa

For very loud sounds the C-filter (Figure 5) is preferred as it approximates the sensitivity of the ear in better way for these sounds at the lower frequencies. So L_A denotes the A-weighted sound pressure level and L_C the C-weighted sound pressure level.

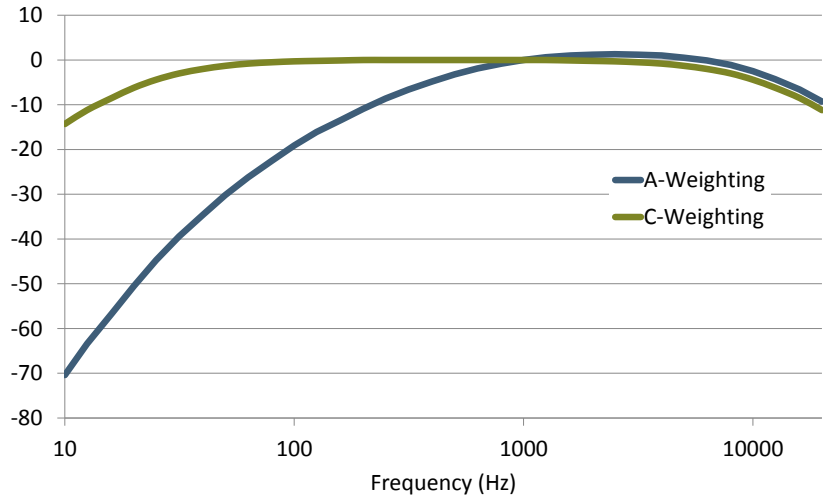

Figure 5 Frequency weighting of sound with the A- and the C-filter.[43]

Peak and maximum sound pressure level

Various regulations are also based on peak and maximum sound pressures and sound pressure levels during a specified period. L_{peak} is the instantaneous sound pressure level. Often sound pressure levels are not measured 'instantaneously' but integrated over a short period of time, such as 0.125 s (denoted as 'Fast' or F) and 1 s (denoted as 'Slow' or S). The maximum sound pressure level in a specified period is L_{max}. $L_{max,peak}$ is the maximum instantaneous sound pressure level and $L_{max,F}$ and $L_{max,S}$ the fast and slow maximum sound pressure level respectively.

The quantities may be weighted using the curves in Figure 5 to account for the sensitivity of the ear. So, *e.g.*, L_{Cpeak} is the C-weighted peak sound pressure level and $L_{Amax,F}$ the A-weighted maximum sound pressure level measured in the 'Fast' mode.

[43] The frequency weighting curves are defined in international standard IEC 61672:2003. See https://en.wikipedia.org/wiki/A-weighting, accessed 12-05-2017 and https://nl.wikipedia.org/wiki/Wegingscurves_A_en_C, accessed 12-05-2017.

Equivalent sound level

When the sound level fluctuates with time, the equivalent sound level over a period of time is determined for a variety of acoustic applications. This equivalent sound level can be expressed as follows:

$$L_{Aeq,T} = 10 \times \log \frac{1}{T} \int_0^T \frac{p_A(t)^2}{{p_0}^2} \mathrm{d}t \text{ dB(A)}$$

with:

- $p_A(t)$: the A-weighted sound pressure at time t
- T: duration of the period considered.

Here the A-weighting is used as indicated by the subscript A before 'eq'.

In the International Standard ISO 1999:1990 (International Organization for Standardization 1990) where this quantity is defined, it is also suggested that the quantity is a measure for occupational noise-induced hearing loss after being exposed daily to workplace noise for several tens of years (a working lifetime). The standard also states that for working days of less than 8 hours the equivalent sound level can be integrated over the 8 hours day using the formula above in order to estimate the risk of hearing impairment. This so-called equal energy principle is often being extended over a full day for environmental noise applications. The integration is depicted graphically in Figure 6. Whether in such cases $L_{Aeq,T}$ is a good metric for risk evaluations over prolonged exposure periods is not always sufficiently empirically ascertained.

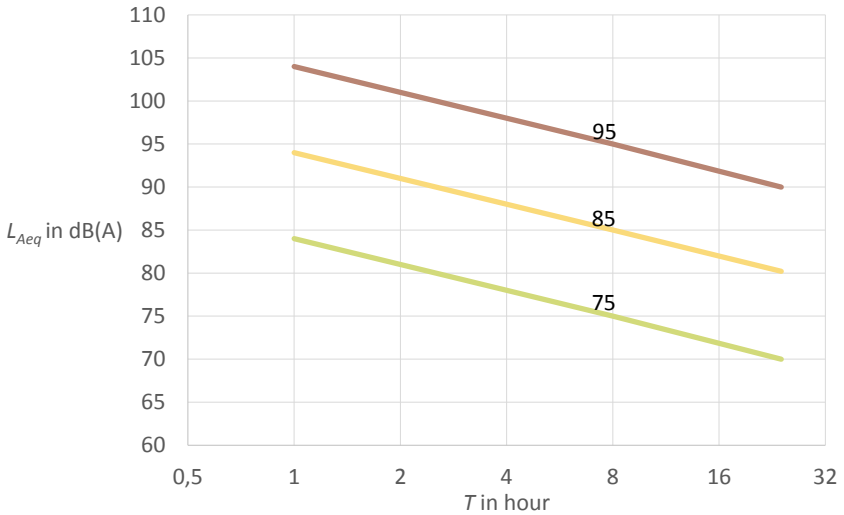

Figure 6 Corresponding values of the equivalent sound $L_{Aeq,T}$ level for period T. The three curves have equivalent sound levels of 75, 85 and 95 dB(A) at T=8h.

Quantities in the EU directive on occupational noise exposure (EU 2003)

The EU directive on occupational noise exposure defines three quantities.

Peak sound pressure (p_{peak})

This quantity is the maximum value of the 'C'-weighted instantaneous noise pressure. The C-filter is shown in Figure 5. In case of referring to the reference pressure of 20 μPa the C-weighted peak sound pressure level $L_{Cmax,peak}$ may also be used.

Daily noise exposure level ($L_{EX,8h}$)

The occupational daily noise exposure level is the equivalent sound level to which a worker or group of workers is exposed on a representative workday. The duration of the workday is normalised to 8 hours (International Organization for Standardization 1990).

Weekly noise exposure level ($\bar{L}_{EX,8h}$)

The weekly noise exposure level is the time-weighted average of the daily noise exposure levels for a nominal week of five eight-hour working days (International Organization for Standardization 1990).

Annex II CAUSES OF TINNITUS

This annex lists known causes of objective (Table 4) and of subjective tinnitus (Table 5).

Table 4 Causes of objective tinnitus, originating from bodily sounds.

arterial pulsatile tinnitus due to vascular disease
carotid stenosis
dissecting carotid aneurism
resonance in the petrosal bone
arterial loop in the internal auditory canal
elevated cardiac output.
enhanced bone conduction perceiving arterial beat
semi-circular canal dehiscence
arterio-venous malformation (AVM)
glomus tympanicum tumour
humming or murmuring of venous origin ("*venous hum*")
intracranial hypertension (with or without obesity)
Arnold Chiari malformation
venous turbulence (with or without malformation)
muscle contractions and tuba-opening sounds
m. tensor tympani (enhanced during tuba dysfunction)
palatoclonus
cervical arthrosis sounds (while rotating head)
temporal-mandibular clicking of joint
clicking of auricular cartilage or tympanic membrane

Table 5 Organic causes of subjective tinnitus.

conductive hearing loss
cerumen plug
otosclerosis
otitis serosa
chronic otitis media
perceptive cochlear hearing loss
menière's disease
permanent noise trauma
presbyacusis
auto-immune inner ear disease
genetic sensorineural deafness
labyrinthitis or cochleitis

retrocochlear neural hearing loss and cerebello-pontine angle pathology
acoustic neurinoma (vestibular schwannoma) and cerebellopontine tumours
cochleovestibular compression syndrome
brainstem- and auditory cortex dysfunction
brain tumours
white matter lesions or demyelinazation
micro- and macro vascular pathology
general or focal cortical dysfunction
including depression
toxicological or pharmacological effects
among other drugs salicylate intoxication
extra-auditory somatic influences
temporomandibular dysfunction
whiplash trauma
cervical pathology
hypertension
upper airway infections

Annex III TINNITUS PATIENT ASSESSMENT

This annex reproduces the consensus of the experts of the Tinnitus Research Initiative on patient assessment and outcome measurement (Table 6).

Table 6 Consensus for patient assessment and outcome measurements (Tinnitus Research Initiative meeting 2006 (Langguth et al 2007)). In each category recommendations are ordered according to their level of significance: A: Essential B: Highly recommended C: Might be of interest

Patient Assessment
Physical examination
A: Otological examination by a specialist
A: Examination of the neck (range of motion, tenderness, muscle tension…)
B: Examination of the temporomandibular function
Audiological assessment
A: Audiometry (pure tone threshold; up to 8 kHz)
B: Immitance audiometry
B: High-frequency audiometry (at least up to 12 kHz)
B: Otoacoustic emissions
B: Loudness discomfort level
C: Auditory evoked potentials
Psychophysialc measures of tinnitus

B: Loudness match
B: Pitch match
B: Maskability (MML)
B: Residual inhibition
Case history
A majority of participants preferred a questionnaire to be filled in by the patient (with access to someone for clarification) rather than at a structured interview. This was not a consensus. It was agreed that as a first step towards consensus a list of those items common to most existing questionnaires should be made. A first attempt to extract such a list is attached.
Questionnaires
A: Validated questionnaire for the assessment of tinnitus severity, which at present can be THI, THQ, TRQ or TQ (it was agreed that in the future a better and more widely validated questionnaire was required)
B: Assessment of tinnitus severity by additional questionnaires, and especially by the THI because it is believed that THI is validated in most languages
C: Assessment of depressive symptoms (e.g. BDI)
C: Assessment of anxiety (e.g. STAI)
C: Assessment of quality of life (e.g. WHODAS II)
C: Assessment of insomnia (e.g. PSQI)
Outcome Measurements
A: Validated questionnaire for the assessment of tinnitus severity, which at present can be THI, THQ, TRQ or TQ (it was agreed that in the future a better and more widely validated questionnaire was required)
B: Assessment of tinnitus severity by additional questionnaires, and especially by the THI because it is believed that THI is validated in most languages
C: Assessment of depressive symptoms (e.g. BDI)
C: Assessment of anxiety (e.g. STAI)
C: Assessment of quality of life (e.g. WHODAS II)
C: Assessment of insomnia (e.g. PSQI)
C: Tinnitus loudness match
C: Maskability (MML)
C: Objective measurement of brain function (functional imaging, electrophysiology)

Abbreviations: kHz, kilohertz; dB, decibel; SL, sensation level; MML, minimal masking level; THI, Tinnitus Handicap Inventory (Newman *et al* 1998); THQ, Tinnitus Handicap Questionnaire (Kuk *et al* 1990); TRQ, Tinnitus Reaction Questionnaire (Wilson *et al* 1991); TQ, Tinnitus Questionnaire (Hallam *et al* 1988); BDI, Beck Depression Inventory (Beck and Steer 1984); STAI, State Trait Anxiety Inventory (Spielberger *et al* 1983); WHODAS, WHO Disability Assessment Schedule (McArdle *et al* 2005); PSQI, Pittsburgh Sleep Quality Index (Buysse *et al* 1989);

COMPOSITION OF THE WORKING PARTY THAT PREPARED THE REPORT

The composition of the Executive Board and the General Board of the Superior Health Council as well as the Council's experts appointed by Royal Decree are available on the following website: composition and mode of operation.

All experts joined the working party in *a private capacity*. Their general declarations of interests as well as those of the members of the Council's Executive and General Boards can be viewed on the SHC website (site: conflicts of interest).

The following experts were involved in drawing up and endorsing this advisory report.

ADANG Dirk	Health and environment	UCL
CIMA Rilana	Behavioural medicine, Audiology	Maastricht University, Behavioural medicine
GARIN Pierre	Audiophonology	Centre Universitaire d'Audiophonologie, CHU UCL
GILLES Annick	Otorhinolaryngology	UZA, University of Antwerp, Dept. ENT and Head and Neck Surgery
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VLAEYEN Johan	Clinical and health psychology	KU Leuven, Health psychology and Maastricht University, Behavioural medicine

The working party was chaired by **Wim PASSCHIER**; the scientific secretary was Eric JADOUL.

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The Superior Health Council is a federal advisory body. Its secretariat is provided by the Federal Public Service Health, Food Chain Safety and Environment. It was founded in 1849 and provides scientific advisory reports on public health issues to the Ministers of Public Health and the Environment, their administration, and a few agencies. These advisory reports are drawn up on request or on the SHC's own initiative. The SHC aims at giving guidance to political decision-makers on public health matters. It does this on the basis of the most recent scientific knowledge.

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